HILLER AIRCRAFT COMPANY, (II)

Design of a Supercharger Inlet Duct

Engineers in the power plant group at Hiller Aircraft Company are faced with the problem of redesigning the engine air intake ducting on a modified version of an existing model helicopter. Two major changes of their model 12-E (Exhibit 1) have resulted in the development of a new model, the 12-L. These changes involve a revised rotor system and the installation of a supercharged reciprocating engine.

Prepared in the Design Division, Department of Mechanical Engineering, Stanford University, by Eugene J. Echterling under the direction of Professor Peter Z. Bulkeley as a basis for student exercises. The assistance of Alfred Bolton and William Lancaster, Jr., of Hiller Aircraft Company is gratefully acknowledged.

Although the supercharger for the engine was not designed by Hiller, all systems supporting the engine and all installation features are designed by the power plant group in Hiller's engineering department. Bill Lancaster is the engineer in charge of designing the power plant installation for the model 12-L. He explained the use of descriptive geometry in his work, "In the design of air intake, exhaust, fuel, and oil systems we quite often have intersections of spherical, rectangular, and cylindrical sections. To simplify design problems and production problems we try to avoid complex intersections as much as possible. For simple intersections, we in the engineering department do not make detailed descriptions on our engineering drawings. For example, the intersection of a cylindrical filler spout and a cylindrical oil tank would be drawn in roughly by the engineer in our group. The drawing would then go to a loftman, an intermediary between the engineering design group and the production group. The loftman would then make detailed drawings defining precisely the line of intersection on both parts. These drawings are made on glass cloth which has a very low coefficient of thermal expansion. The drawings are reproduced photographically on sheet metal from which production templates are made.

"Occasionally, however, exact lines of intersection must be known by the design engineer. This occurs when an intersection involves design as well as production considerations."

Hiller Aircraft Company

Stanley Hiller, Jr., founder of Hiller Aircraft Company, began experimentation on his first helicopter in 1941 at the age of 16. Following successful flights in 1944 of the XH-44, the world's first coaxial rotorcraft, Hiller left his studies at the University of California to devote full time to the newly incorporated United Helicopters, Inc., later to be known as Hiller Aircraft.

Today Hiller is the world's largest producer of light helicopters, producing approximately 225 ships per year. The distribution of the company's business is:

United States Army	80%
Foreign military	5%
Domestic civilian	10%
Foreign civilian	5%

The Hiller plant is located at Palo Alto, California, 30 miles south of San Francisco. Approximately 1000 people perform research, administration, engineering, manufacturing, testing, and sales functions at the 61 acre site. An additional office is maintained in Washington, D.C. Hiller Aircraft recently became a subsidiary of Fairchild Stratos Corporation, an aircraft manufacturing company founded in 1925. They are now called Fairchild Hiller Corporation. Fairchild, based in Germantown, Maryland, produces space vehicles, aircraft, aerospace components and electronics in a country-wide network of plants. Total employment, not including Hiller, is about 3,500. Some of the more famous Fairchild products include the F-27 turboprop airliner and the "flying boxcar" used extensively by the Air Force during the Korean War.

Development of the 12-L

The present model 12-E is a further development of the original model UH 12-A first certified by the Federal Aviation Agency in 1949. The UH 12 has evolved through the A, B, C, and D models to the present E model. The 12-E is a three passenger model powered by a 305 horsepower 6 cylinder Lycoming engine. This model presently holds six official world speed records -- recently clocking 123.77 mph in level flight at sea level.

The 12-E is widely used in both commercial and military applications. Commercial uses include placing utility poles and towers in rugged country, stringing power lines, assisting the construction of off-shore drilling rigs, and aerial spraying of forest and cropland. Military uses include aerial reconnaissance, medical evacuation, and limited troop movement.

Bill Lancaster, an engineer in the power plant group, explained some of the factors which led to the development of the model 12-L. "In any type of aircraft operation, the ability to perform satisfactorily at high altitude is very important. Since early helicopter development work was principally concerned with problems of dynamics, control, and rotor systems, satisfactory sea level performance for useful purposes was often marginal. As a result, high altitude performance was unsatisfactory. It soon became apparent that to take full advantage of the helicopter's ability to hover and get in and out of rough terrain at high altitudes, performance needed to be improved. There are several ways of doing this. One way to improve performance is to increase engine displacement. This increases engine weight and cost, however. Another way is to supercharge the engine. Since weight in aircraft design is always a principal factor, comparisons were made of engine weight per

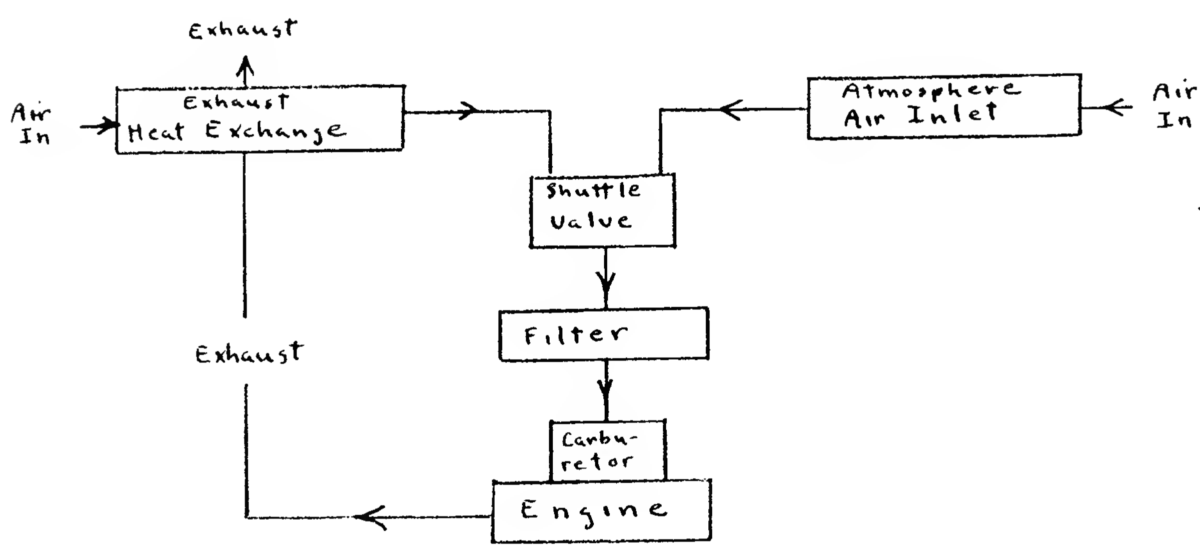
horsepower required to obtain the desired altitude performance. The results led to the selection of the supercharging method. The model 12-L engine is a supercharged version of the engine in the 12-E."

Regarding engine design, there is a basic difference between the aircraft industry and the automobile industry. In the automobile industry, each manufacturer will produce both body and engine for all models in their line. In the aircraft business, this is not so. There are separate airframe manufacturers and engine manufacturers. Hiller is an airframe manufacturer. Bill Lancaster explained, "At Hiller, the power plant group is mainly concerned with engine installation and design requirements. The engineering work covers air intake, exhaust, engine cockpit controls, and fuel and oil systems. In addition, we test and develop the engine installation to meet the Federal Aviation Agency (FAA) regulations for certification. No overall production engine design is done by Hiller."

The supercharger for the Lycoming engine was not developed by either Hiller Aircraft or Lycoming. It was designed and is produced in Los Angeles by the Airesearch Division of the Garrett Corporation. Airesearch has several standard superchargers which they offer to diesel, automobile, and aircraft engine manufacturers. Lycoming did, however, work with Airesearch in developing the supercharger for this engine. Airesearch is interested in high alitutde superchargers not only for aircraft, but also for construction equipment used at high altitudes.

Intake Air Duct

With the addition of the supercharger certain changes are necessary for installation of the engine in the new model 12-L which has the same airframe as the 12-E. One of these changes is the location of the intake air filter and duct-work. For the previous model, a block diagram of the intake air flow is



The shuttle valve allows air flow either directly from the atmosphere or through a heat-exchanging duct mounted on the exhaust pipe of the engine. This valve is manually controlled. Normally the valve permits the flow of air directly from the atmosphere. However, when an indicator mounted on the instrument panel shows that the carburetor venturi[1] temperature approaches 32° F, the pilot switches the valve to the position for air flow through the heat exchanger. This prevents carburetor venturi icing. Bill Lancaster elaborated on this design, "The heat exchanger is simply a shroud around a portion of the exhaust pipe. The incoming air is heated as it passes between the walls of the heat exchanger and the exhaust pipe. Little quantitative design was done here. We merely wanted a smooth flow of warm air to adequately meet the minimum requirements established by FAA regulation."

The filter used in the model 12-E consists of 2 cylindrical paper filter elements (Exhibit 2) stacked end to end in the filter housing. The air enters from the outer surface of the filters, passes through the paper filter elements, and is ducted from the center of the filters to the carburetor. The area of the filtering surface is approximately three times that which is necessary for proper air flow when the filters are clean. This is to provide continued adequate air flow as the filter begins to clog with particles removed from the air stream. Depending upon the climatic conditions, the filter requires checking for replacement every 50 to 100 hours.

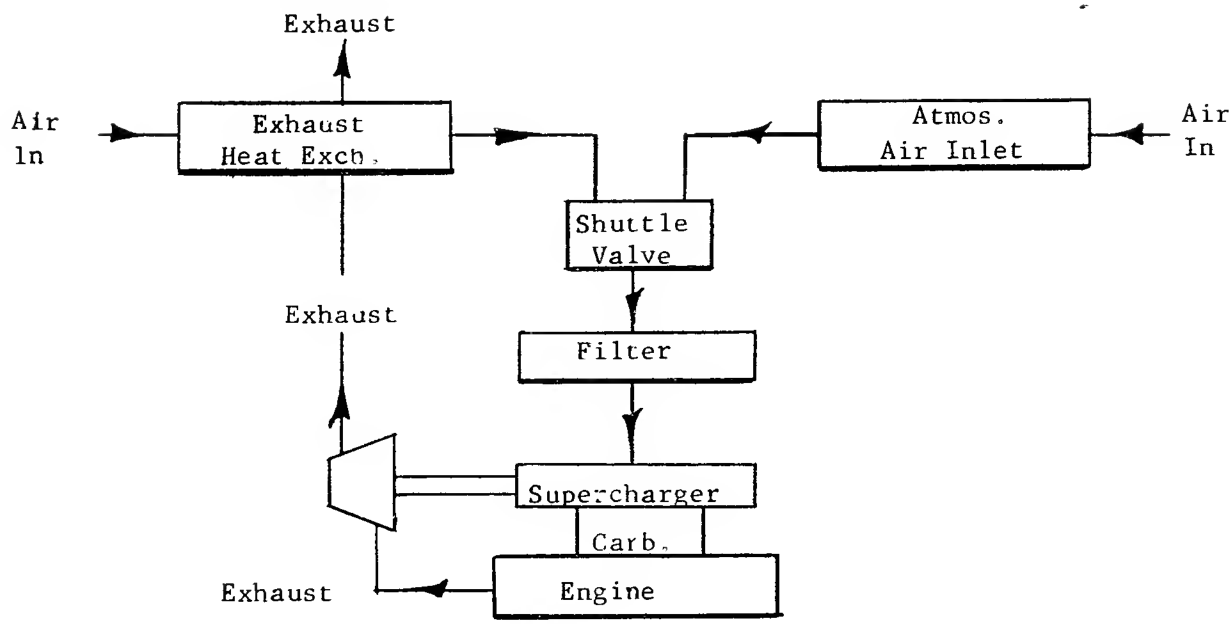
The intake ductwork on the 12-E (Exhibit 3) combines shuttle valve and filter housing in one assembly which is referred to as, and resembles, a "banjo". Designed about 8 years ago, it has been used on the UH-12 models D and E. Original versions of the "banjo" were made of laid-up fiberglass. The first step in the lay-up process is the production of a solid plaster hand-made "master" model of the shpae. Next, a thick fiberglass skin is laid-up around the model. The skin consists of small strands of fiberglass suspended in plastic resin. After curing, the fiberglass skin is cut into 2 pieces and removed from the original plaster model. The two pieces are then used as the female production mold from which plaster forms identical to the hand-made "master" are made. A fiberglass skin is laid up around each of these plaster forms. After the skin cures, the plaster is soaked, broken, and washed away, leaving the hollow fiberglass "banjo" ready for trimming and fitting with the shuttle valve and mounting brackets.

For the past eight years the "banjo" has proven itself as an acceptable design. Hiller has found that reports from helicopter users show no reason for a change in this assembly on the older model 12-E.

---

1. venturi - a constriction in a fluid transport duct which becomes a region of low pressure during fluid flow.

The air intake flow diagram for the new model 12-L is



In discussing considerations of redesigning the old "banjo" for use on the model 12-L, Bill Lancaster of the power plant group explained, "There is an important difference between helicopter engine and automotive engine operation. Helicopter engines operate at constant speed, whereas automobile engines operate at variable speed. The models 12-E and 12-L both have the Lycoming 540 cubic inch displacement engine which operates at 3200 RPM. In the supercharged 12-L model, there is no evidence that suggests an increase in filter area will be needed. As a result, no significant functional change in the intake air ducting concept is planned. The configuration of the old "banjo" will be changed only as required to fit the new installation.

The most significant change affecting the intake air duct is the added space requirement of the supercharger. In the model 12-E the filtered air duct connects directly with the carburetor; in the model 12-L it connects directly with the supercharger. Because the new supercharger projects out farther from the engine than the carburetor does in the old model, the air filter must be moved.

Since the airframes of the two helicopters are the same, the baggage box (Exhibit 4) will be used on both models. In the preliminary design of the new duct work, the engineer felt it would be simplest to alter the shape of the filter housing so that it cleared the baggage box. He believed this would involve fewer changes than would be necessary if the baggage box were moved. He commented, "We felt a small chamfer[1] on the filter housing was the best way of handling this interference problem.

1. chamfer - a beveled edge

The power loss caused by this very small restriction to air flow was too small to measure."

The upper portion of the new "banjo" is to remain the same. This is to permit the use of the same shuttle valve, mounting brackets and air entry ducts on both models.

In both models all intake duct-work is rigidly attached to the engine and must be free to move with the engine in its cushioned mounts. The engine itself is gimballed[1] on its mounting structure. Relative to the framework of the helicopter, the engine can rotate about a vertical axis plus or mimus 2° (plus 2° maximum power, minus 2° during backfire); it can raise .96 inches and lower .3 inches from its neutral point. As the engine swings on its neutral gimbal point, the bottom of the engine can move fore and aft plus or minus 1 inch and laterally plus or minus 1 inch. This pivoting motion is limited by the cushioned mounts seen in Exhibit 5. Consideration must be given to engine motion when designing any ductwork attached to the engine. Clearance must be provided between components on the engine and hardware attached to the airframe.

Completion of Duct Design

Al Bolton is the engineer designing the intake duct on the 12-L. From layout drawings of the supercharged engine mounted in the airframe (Exhibit 6), he has determined where the relocated filter housing must be mounted to provide direct ducting to the supercharger and clearance with existing hardware. Several reference points of the design are fixed. These are the atmospheric air entry point, the heated air entry point, and the supercharger entry point. The previous design of the upper portion of the duct (containing the shuttle valve) and the filter housing will remain unchanged to reduce engineering and tooling costs. Their orientation relative to one another is shown in Exhibit 7. Al must now design the transition section of the duct between filter housing and shuttle valve. He explained some of the design considerations, "To minimize power loss, we want smooth air flow through the ducting. Irregularities in duct cross section, obstructions in the air stream, and rough interior surfaces can cause resistance to air flow, resulting in an increased pressure drop through the duct. Since a pressure drop through the duct can cause reduced engine performance, smooth air flow becomes an important requirement in duct design."

Abrupt changes in duct cross-sectional area can also cause pressure losses. To reduce these losses, any cross-sectional area changes should be made gradually. Al said the cross-sectional area in the transitional section of the duct should be no smaller than the area just below the shuttle valve.

He further explained some air flow considerations, "To provide proper distribution of air around the filtering elements, it is best to have the air stream enter the filter housing in a direction tangential to the

---

1. gimballed - supported with freedom to tilt in any direction.

cylindrical wall of the housing. This results in smoother air flow around the filter elements, utilizing more of their surface area. If the air is brought in radially, more turbulent flow occurs and air flow is not evenly distributed around the periphery of the filter. This results in an increased pressure drop across the filter and subsequent power loss."

Bill Lancaster said he used the figure of 40 miles per hour as the approximate maximum air speed in the section of the duct below the shuttle valve. The fillet where this section meets the cylindrical filter housing is to have a minimum radius of 1/4".

Although early models of the duct will be made of laid-up fiberglass, as production increases it is expected that the unit will be fabricated from metal. In the experimental model shown in Exhibit 8, the assembly is welded from drawn aluminum sections.

Exhibit 1: Hiller Model 12-E (Military Version)

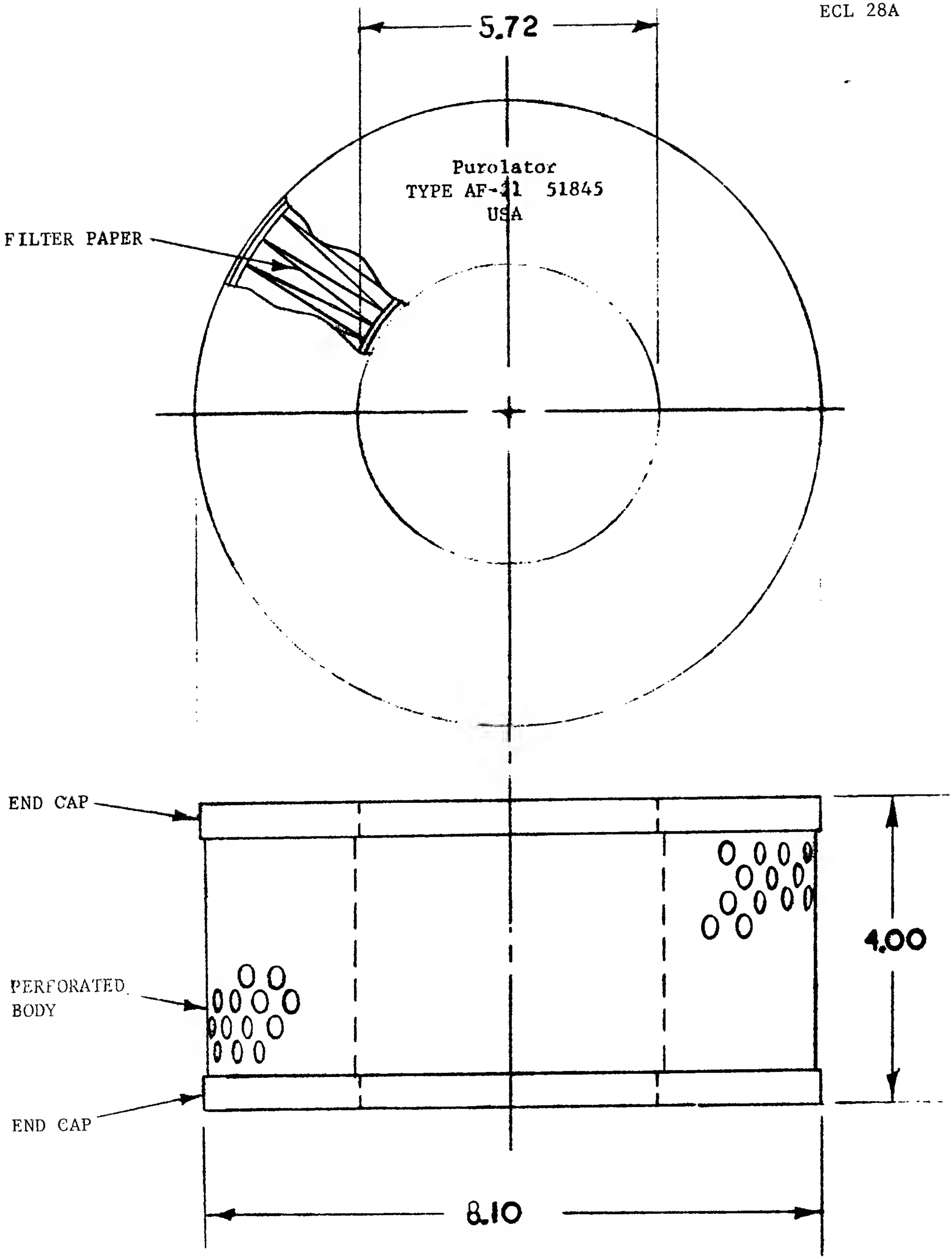


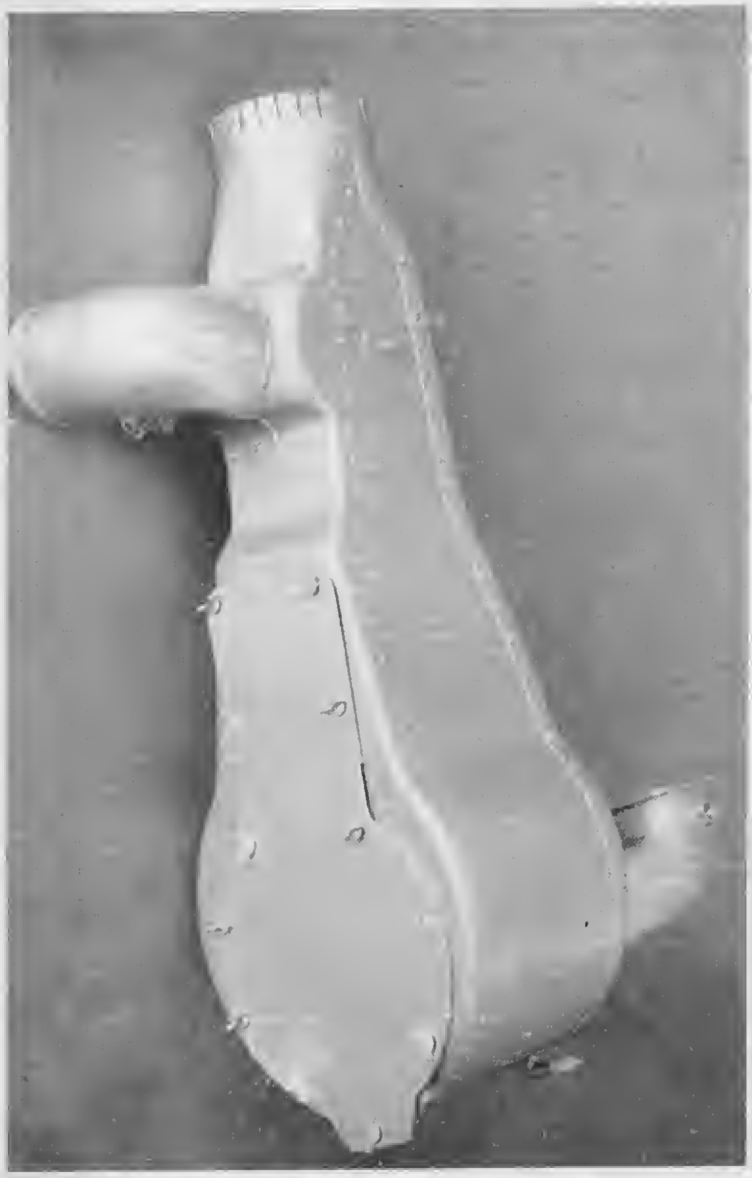
EXHIBIT 2. Filter Element

ATMOSPHERIC AIR INLET

HEATED AIR INLET

CARBURETOR MOUNTING FLANGES

Exhibit 3: Intake Duct for Model 12-E.
(Metal Version)



<u>Exhibit 3 (cont.)</u>: Intake Duct for Model 12-E.
(Metal Version)

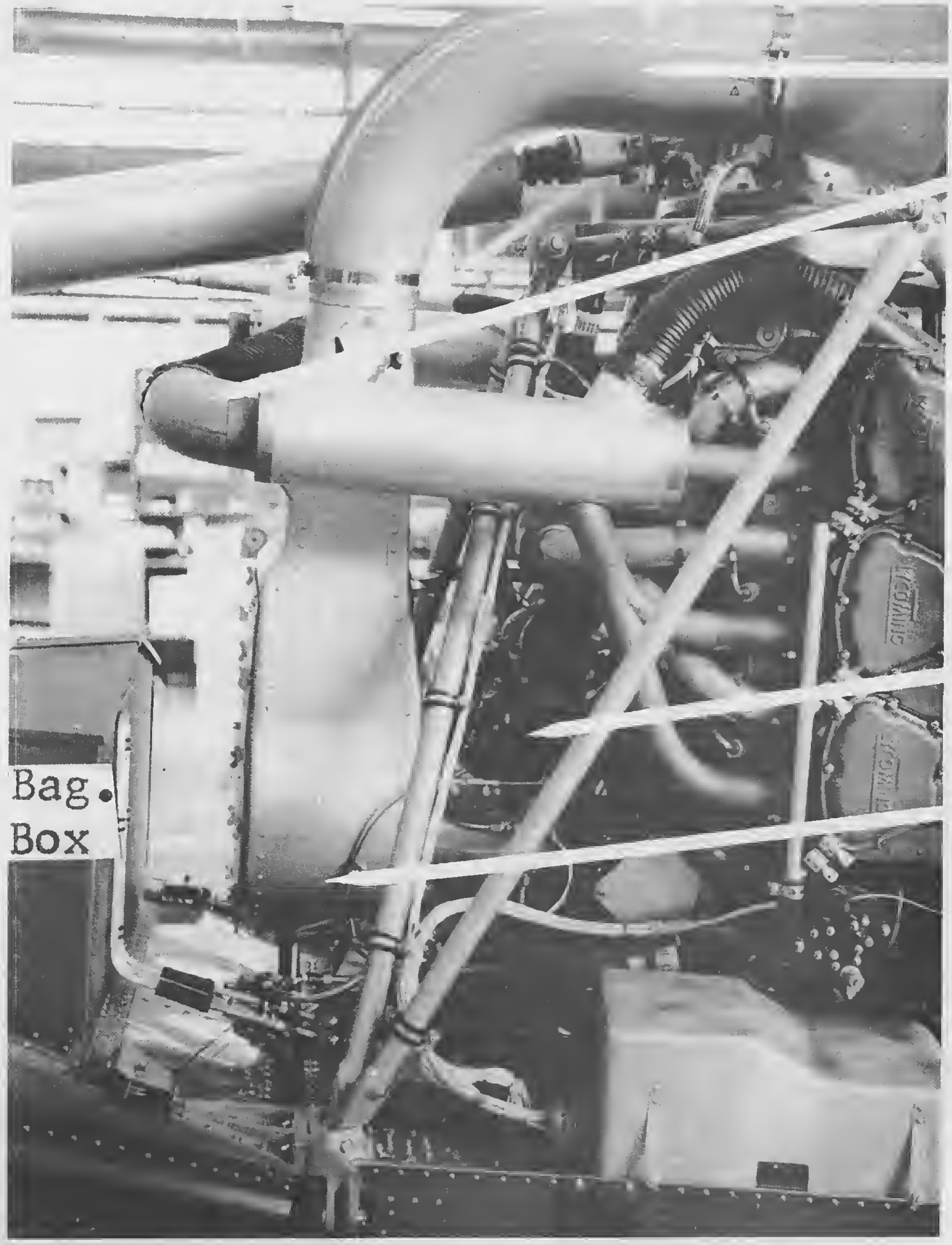
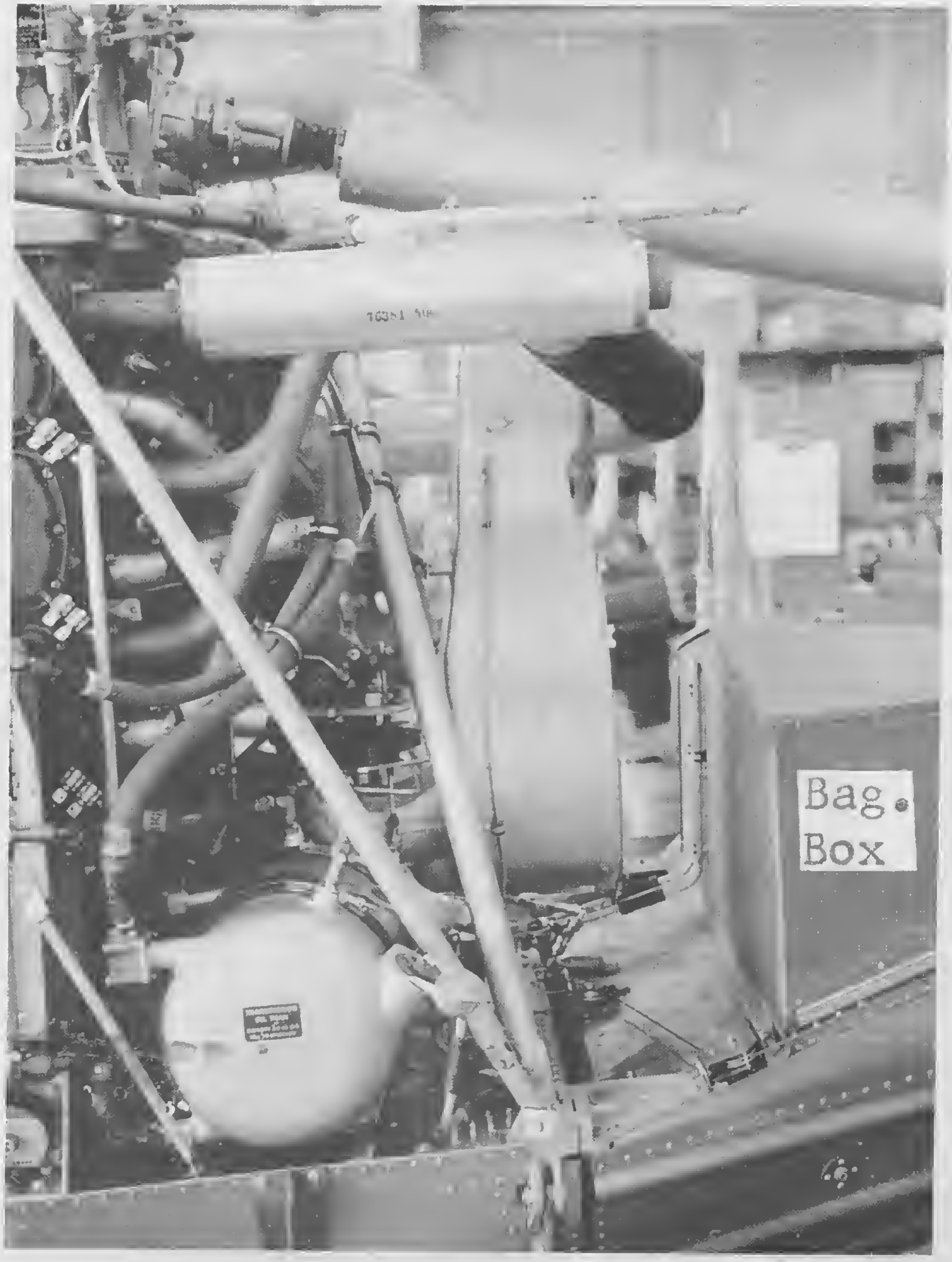


Exhibit 4: Baggage Box Clearance on Model 12-E.



FRONT REAR

<u>Exhibit 4 (cont.)</u>: Baggage Box Clearance on Model 12-E.

Exhibit 5: Experimental Model 12-L

Legend-
1. Supercharger
2. Filter Housing
3. Baggage Box
4. Hot Air Duct
5. Heat Exchanger

← FRONT REAR →

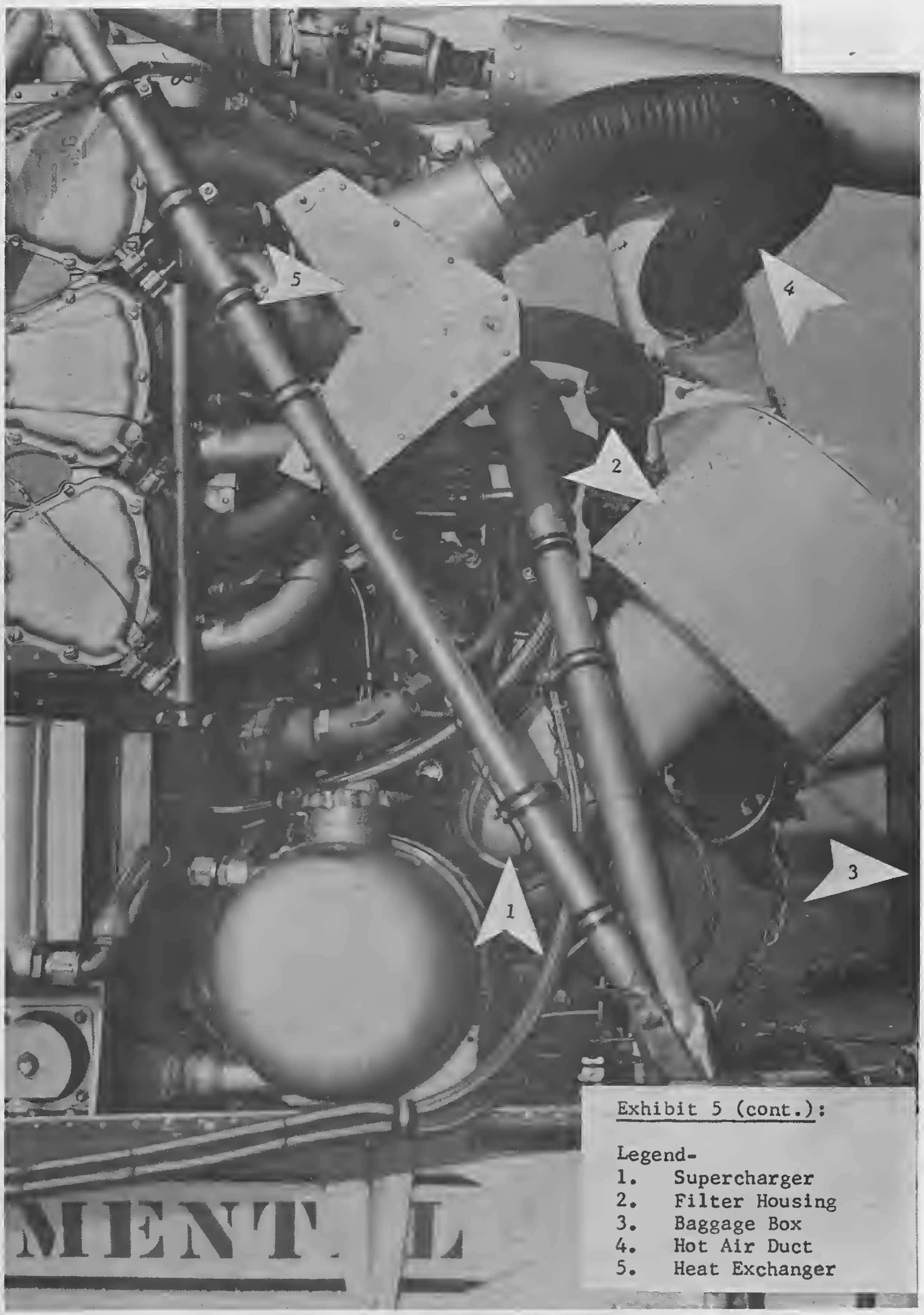


Exhibit 5 (cont.):

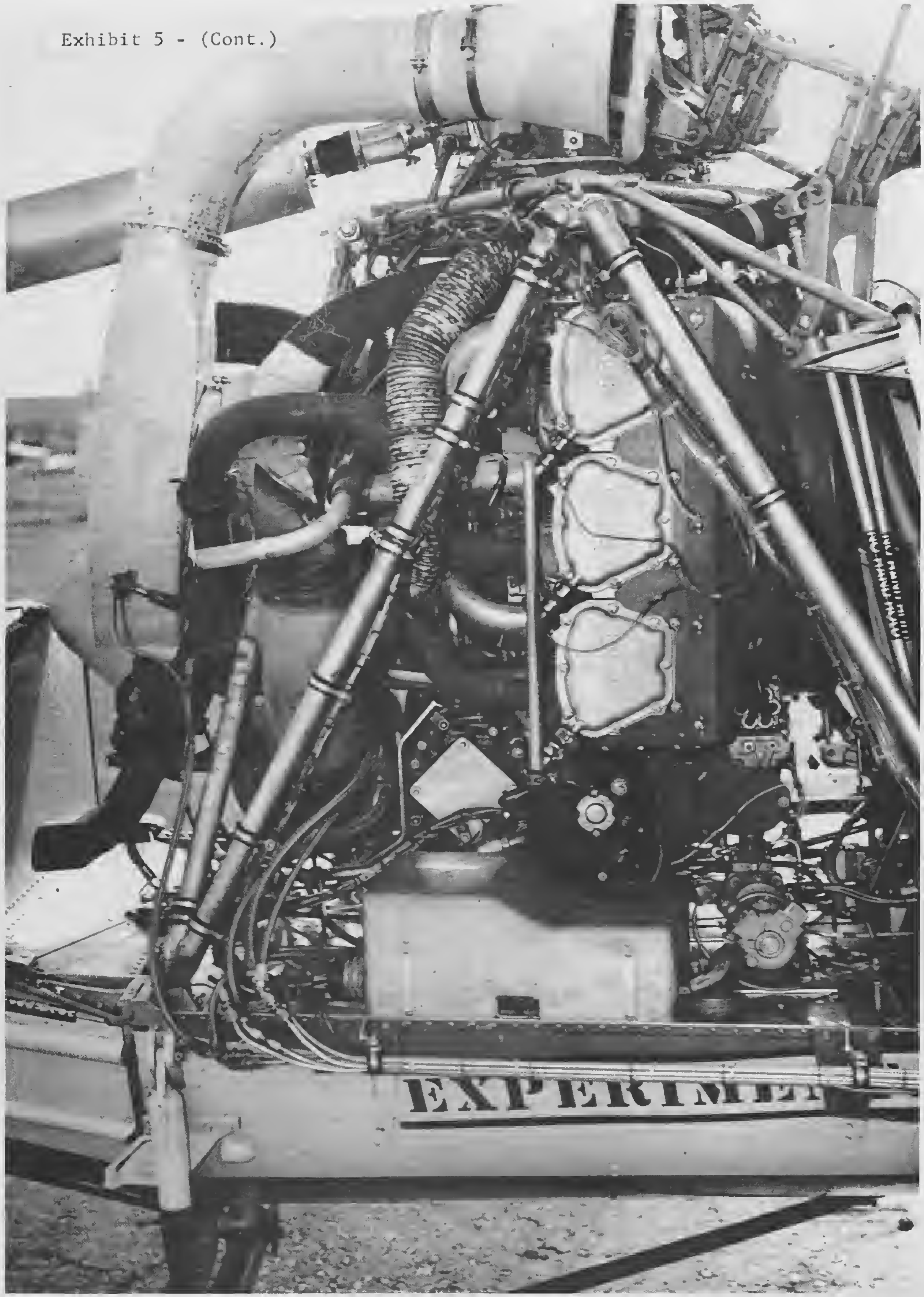
Legend-
1. Supercharger
2. Filter Housing
3. Baggage Box
4. Hot Air Duct
5. Heat Exchanger

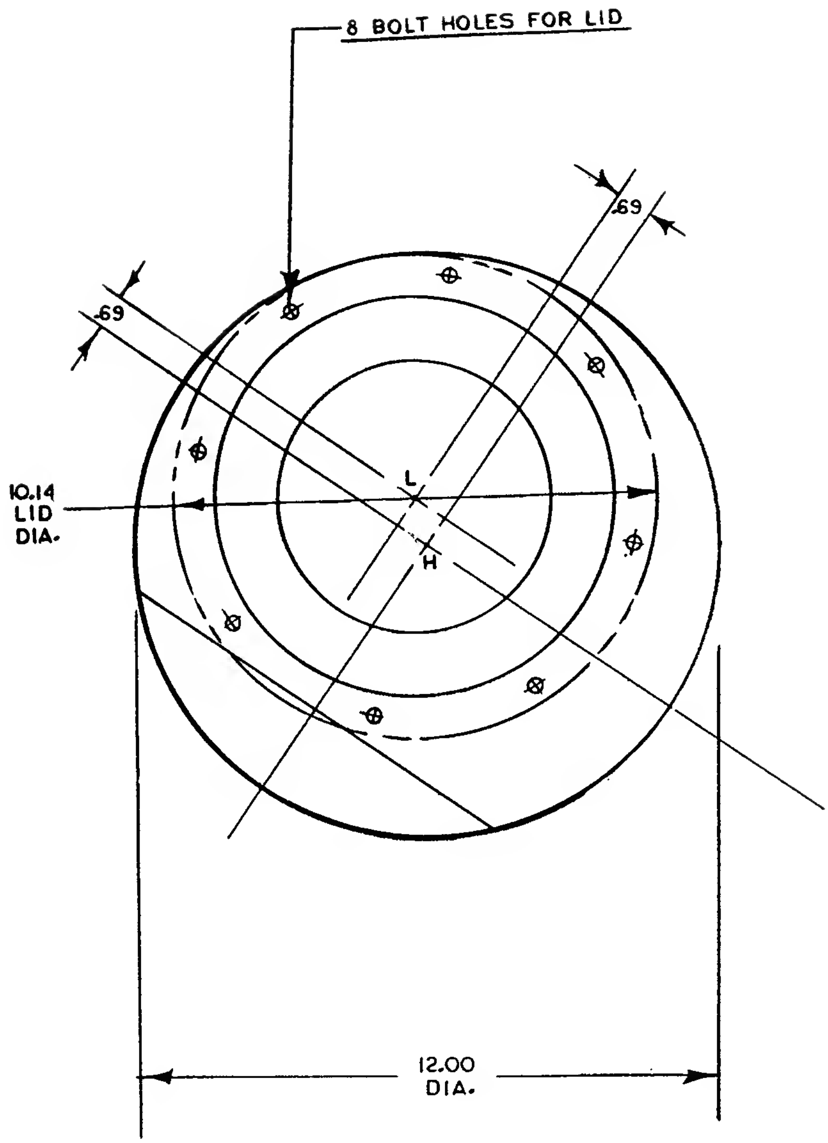
← FRONT REAR →

Exhibit 5: (cont.)

Legend:
1. Supercharger
2. Engine Exhaust Manifold Junction (Engine Exhaust to Turbine)
3. Exhaust from Turbine to Atmosphere
4. Exhaust Bypass to Atmosphere
5. Air Intake

Exhibit 5 - (Cont.)





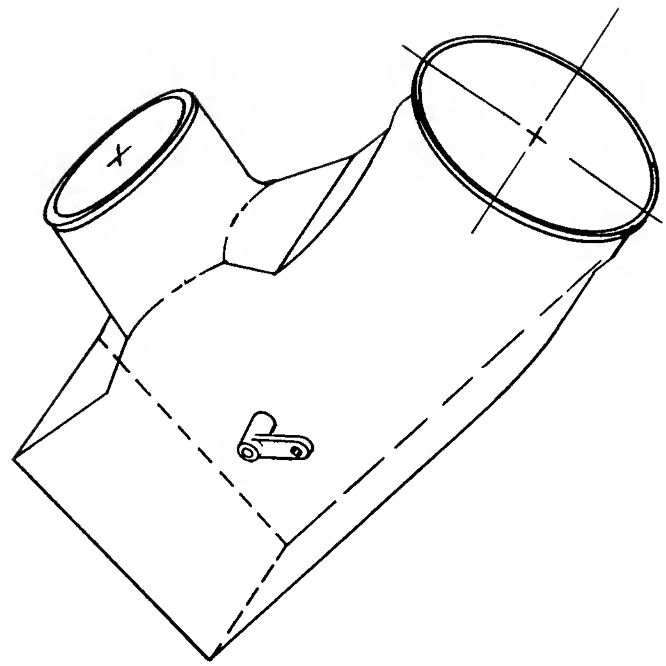
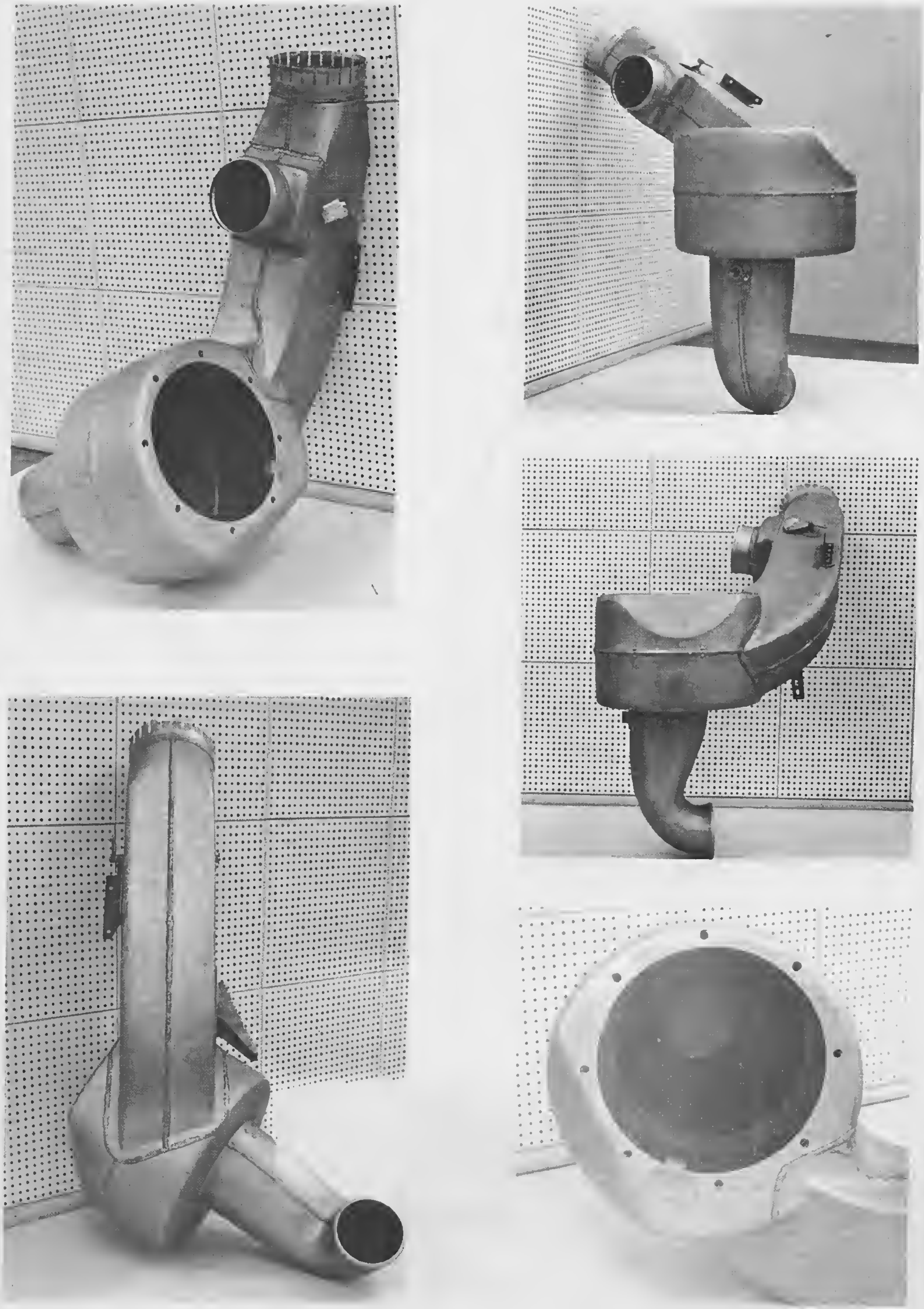


EXHIBIT 7-B :

VIEW O

1/4 SCALE



<u>Exhibit 8</u>: Experimental Intake Air Duct for Hiller Model 12-L.

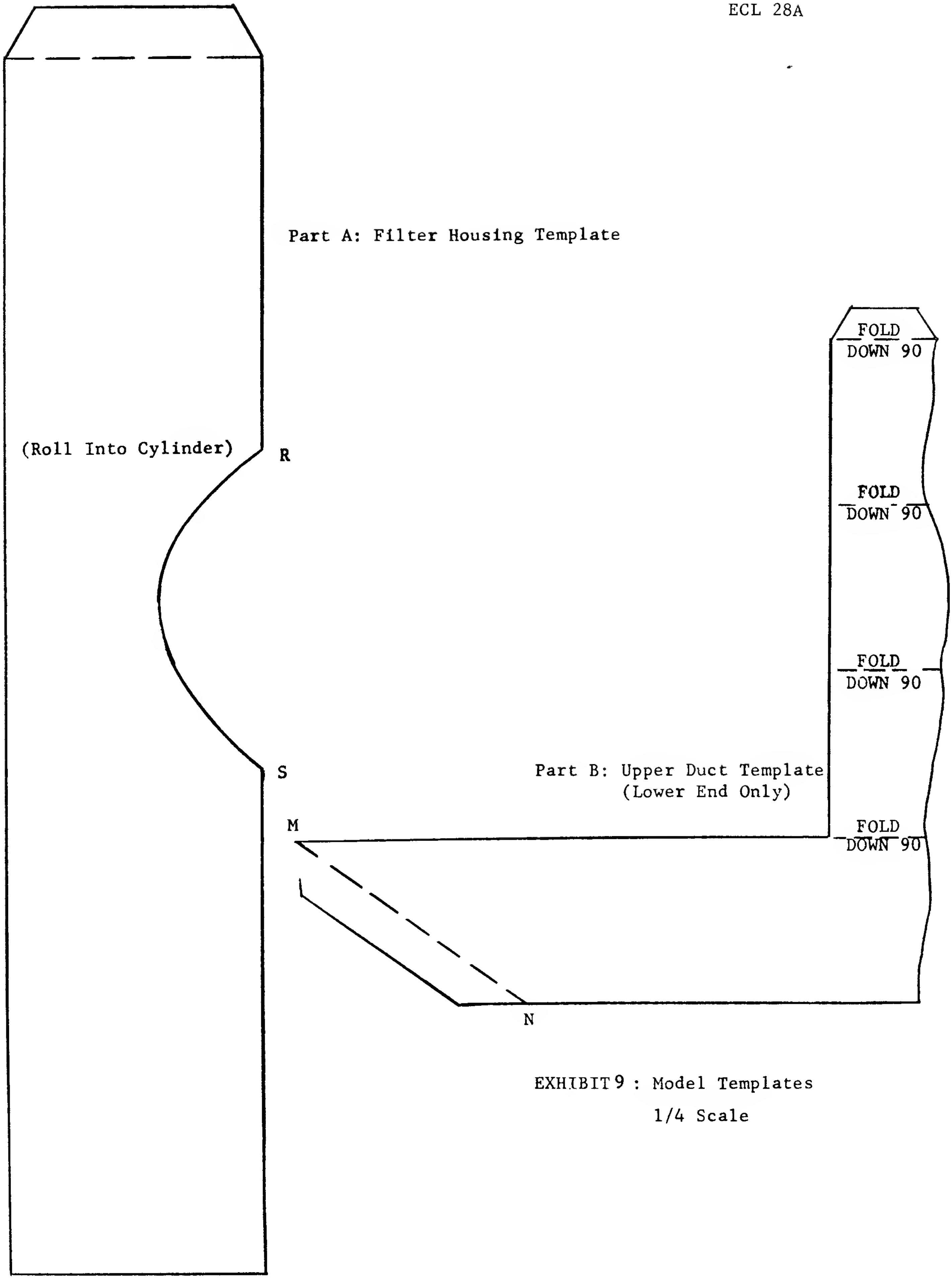
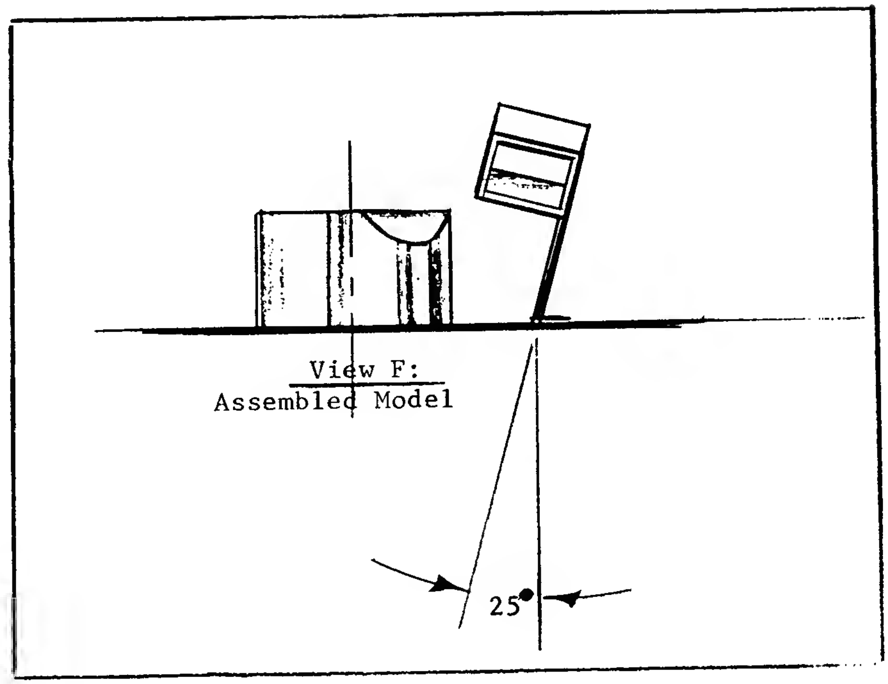


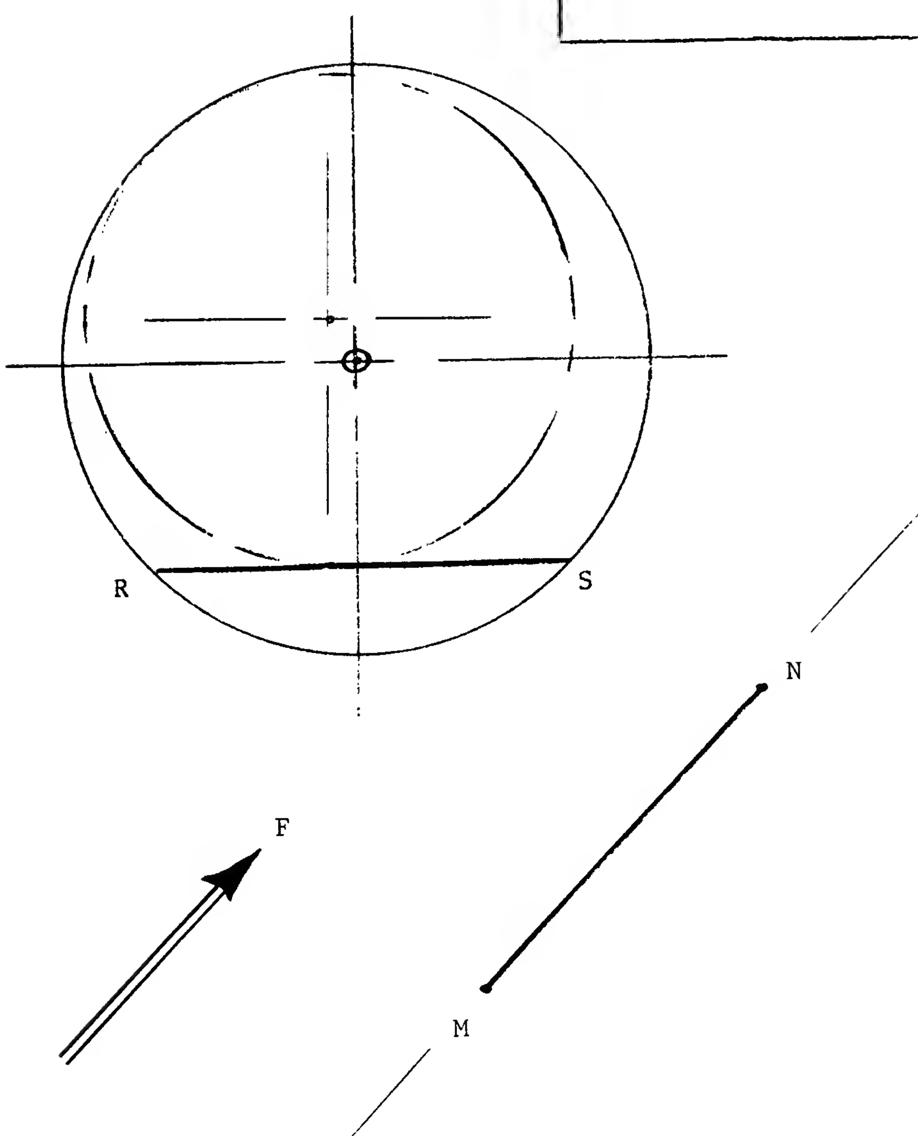
EXHIBIT 9 : Model Templates

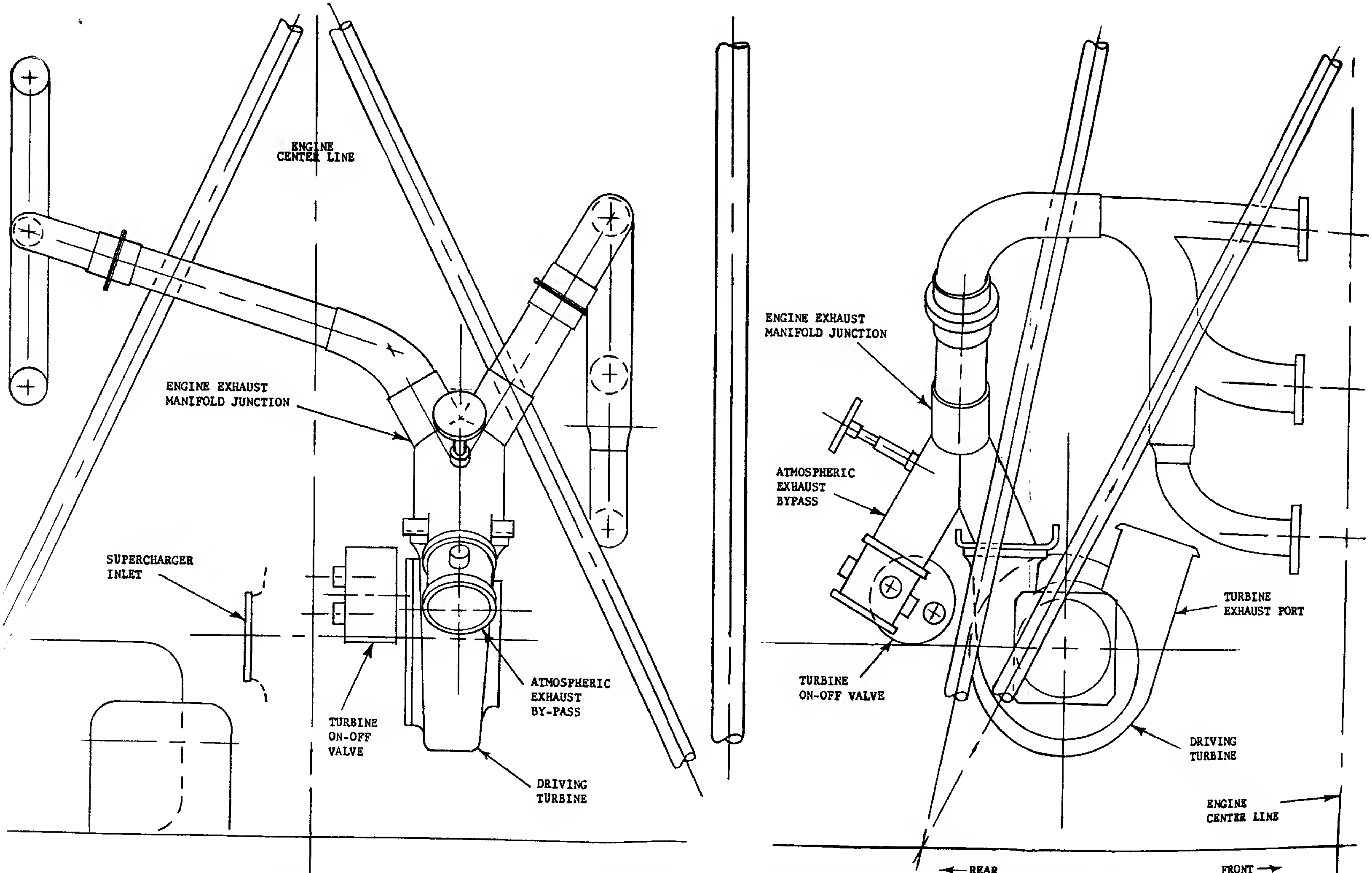
1/4 Scale

Locate Part A on Circle O.

Locate Part B on Line M-N.







VIEW FROM REAR OF HELICOPTER

VIEW FROM RIGHT SIDE OF HELICOPTER

Exhibit 6: Layout of Intake Duct Surroundings (Copied from the original drawing made by Al Bolton of Hiller Aircraft).

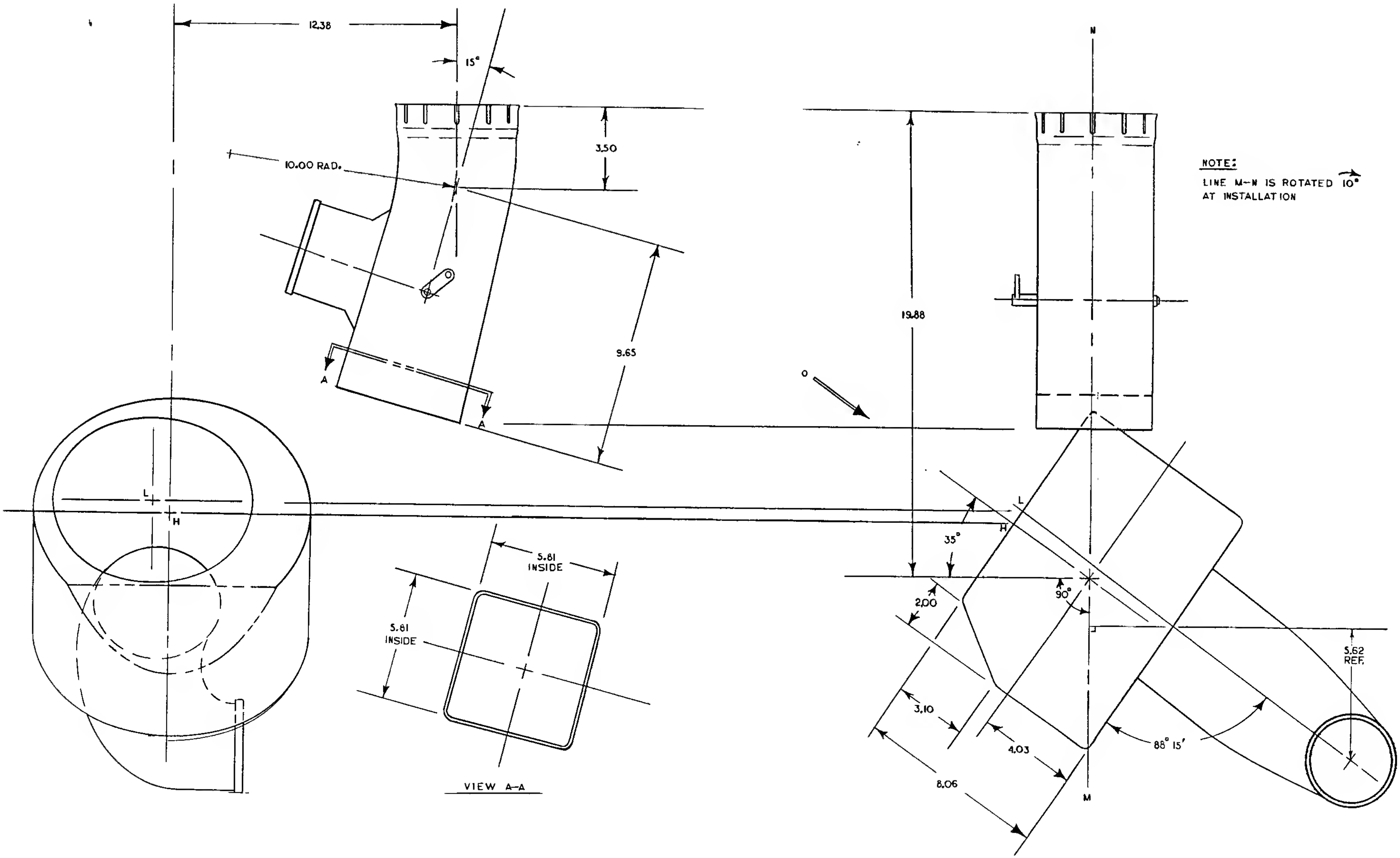


EXHIBIT 7—A: FILTER HOUSING AND SHUTTLE VALVE ORIENTATION

1/4 SCALE

Hiller Aircraft Company II (B)

Filter Housing Clearance Considerations[1]

With the addition of a supercharger to Hiller Aircraft's older model 12-E helicopter, interference problems between the engine air intake system and components attached to the airframe arose in the new model 12-L which were not present in the model 12-E. One such problem faced by Hiller engineers was the interference between the filter housing in its new location and the baggage box, which is common to both models. Bill Lancaster, a power plant engineer working on the model 12-L, said that the intake air duct system must assure that no interference occurs under all conditions ranging from rest to maximum engine movement during operation.

Airframe Dimensioning

In the airframe industry a cartesian coordinate dimensioning system is commonly used, but axes are not referred to as X, Y, and Z. Instead, the terms "station","buttock", and "water line" are used. With the veritcal line through the neutral engine gimbal point as a reference, points measured fore and aft are called "station points", and lateral measurements are referred to as "buttock points". Normally, the vertical line through the gimbal point is at station point 100 (with station points increasing from front to back, i.e., station point 110 is 10 inches aft of the gimbal point). In this particular ship, however, the gimbal point was assigned station point 85. Buttock points are negative on the left hand side and positive on the right hand of the seated pilot. Points measured vertically are referred to as lying on certain "water lines", with the ground line of the ship referred to as "zero water line". In this model the gimbal point is located at water line 63.12, meaning it is 63.12 inches above the ground when the helicopter is at rest. This dimensioning system using station, buttock, and water lines occurs as a result of early aircraft loftmen having been trained in the ship-building industry.

Filter Housing Clearance

One quarter scale layout drawings of the engine, engine mounts, and airframe were used by Hiller engineers to determine interference problems resulting from relocation of the intake duct. The layout drawing used to determine the size and location of the chamfer on the filter housing is shown in Exhibit B-1. Dimensions scaled from the original layout drawing are given in Exhibit B-2. This drawing gives locations of the filter housing and baggage box in their neutral position.

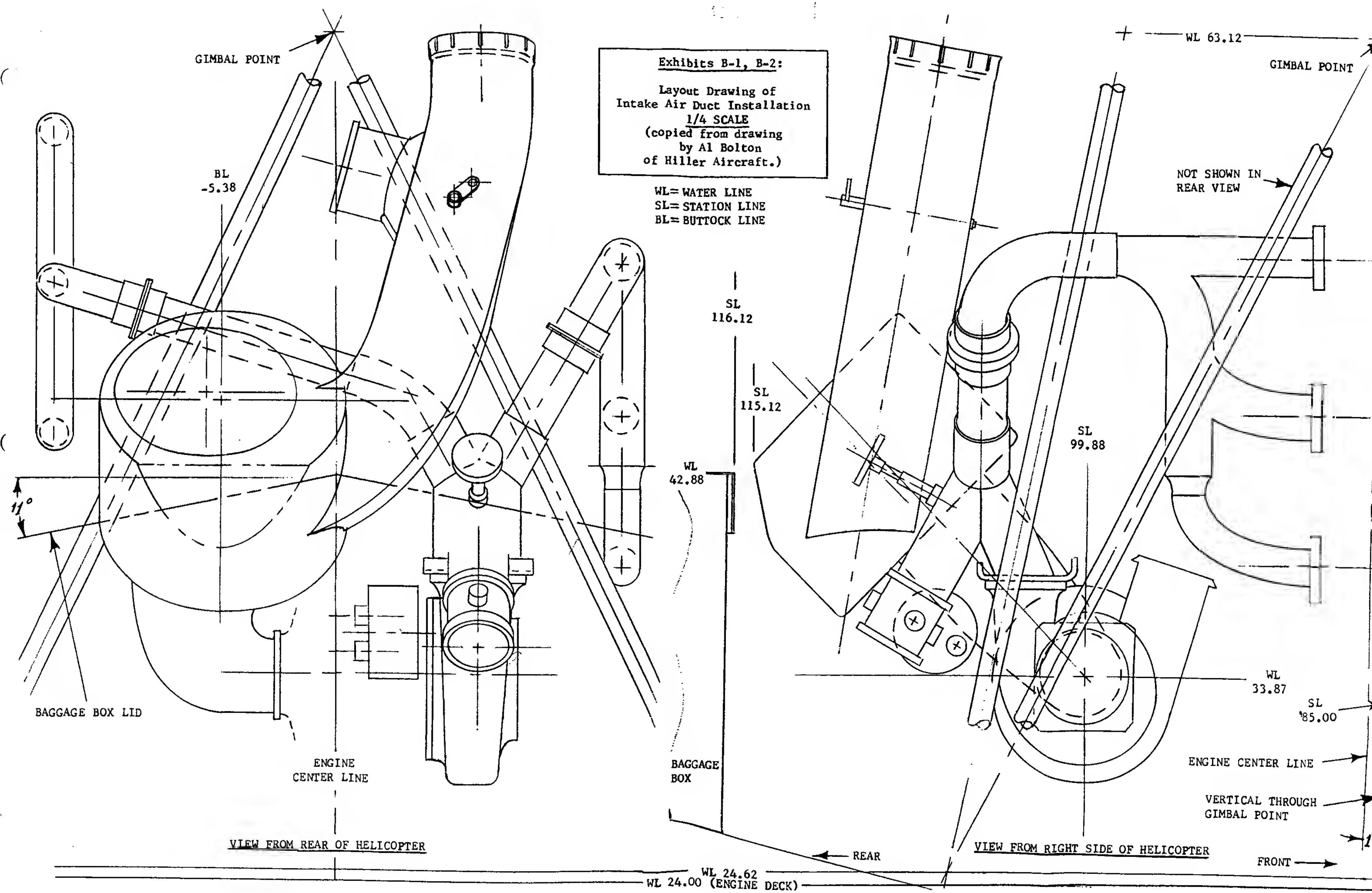
---

1. This case is based on a helicopter redesign problem described in "Hiller Aircraft Company, II (A) Design of a Supercharger Inlet Duct".

Prepared in the Design Division, Department of Mechanical Engineering, Stanford University by Eugene J. Echterling under the direction of Professor Henry O. Fuchs as a basis for student exercises. The assistance of Alfred Bolton and William Lancaster, Jr. of Hiller Aircraft Company is gratefully acknowledged.

In Exhibit B-3 is shown a plan and left side view of filter housing, baggage box, engine support structure and bottom cushion mounts at rest. Under these conditions, the center line of the engine is tilted back 1° from the vertical through the gimbal point. This tilting is done by adjusting the rear lower cushion mount (Exhibit B-4) at installation. These mounts are constructed to allow the bottom of the engine to move plus or minus one inch laterally and plus or minus one inch fore and aft. Bill Lancaster explained that these motions can combine to give a point on the bottom of the engine a locus which is very close to a square 2 inches on a side. He said the radius on the corners of the square was so small as to give an insignificant variation from a square.

The gimballing structure also permits the engine to rotate about a vertical axis plus or minus 2° (plus 2° at maximum power, minus 2° during backfire). In addition, rubber mounts in the gimbal structure and deformation of the metal supports permit the engine to raise 0.96 inches and lower 0.3 inches under various loading conditions. Of this deformation, approximately 90% is due to deformation of the rubber mounts and approximately 10% is due to metal deformation in the engine mounting system. This deformation is determined by static ground tests performed by the ground test group using load information gathered by the flight test group from in-flight tests of engine loading under various conditions. All of the engine motions may combine and must be considered when determining clearamce between engine-mounted and airframe-mounted components.



Exhibits B-1, B-2:

Layout Drawing of
Intake Air Duct Installation
1/4 SCALE
(copied from drawing
by Al Bolton
of Hiller Aircraft.)

Exhibit B-3a: Plan View of Filter Housing, Baggage Box, and Engine Mounts at Rest.

1/4 SCALE

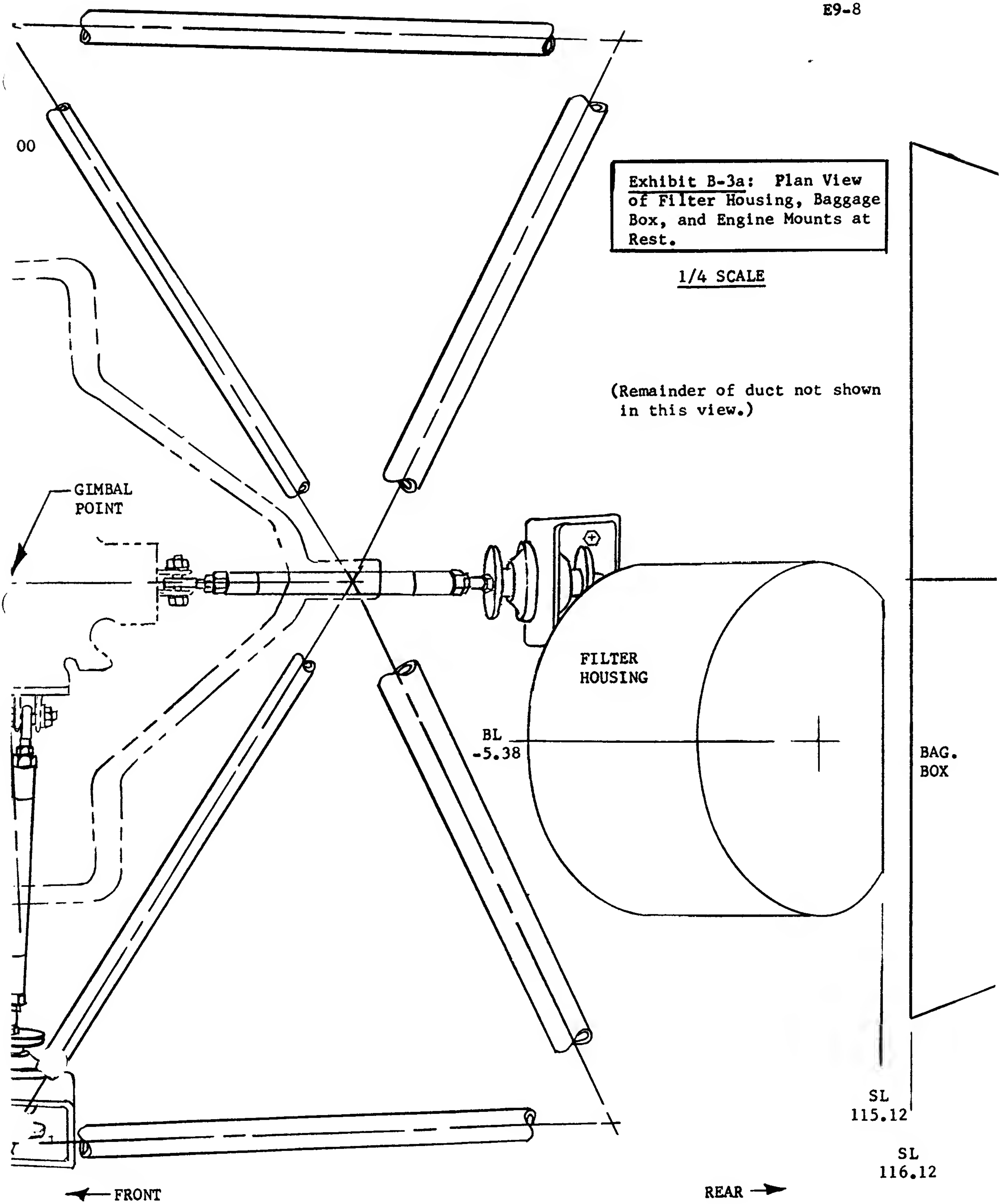


Exhibit B-3b: Left Side View of Filter Housing, Baggage Box, and Engine Mounts at Rest.

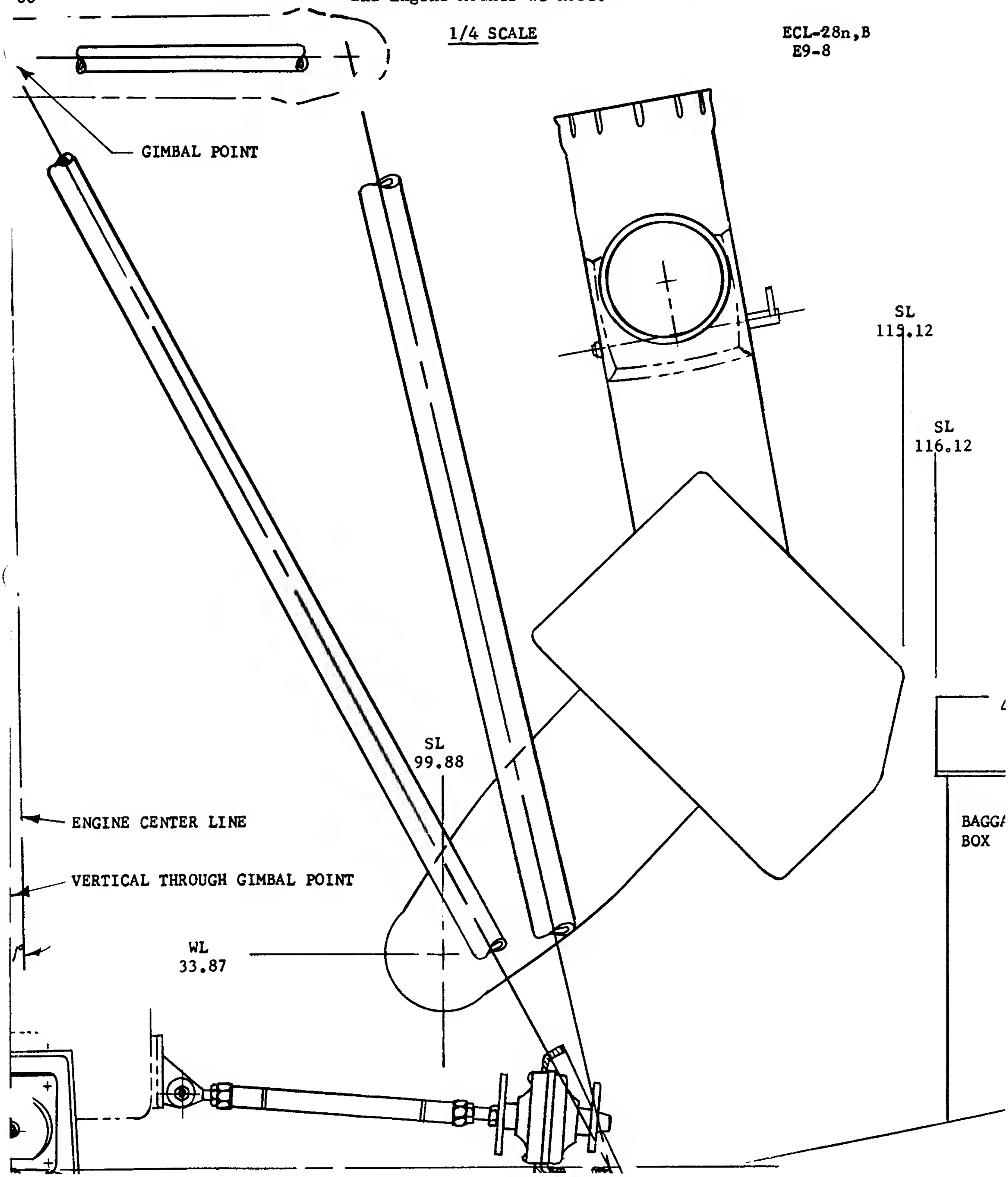
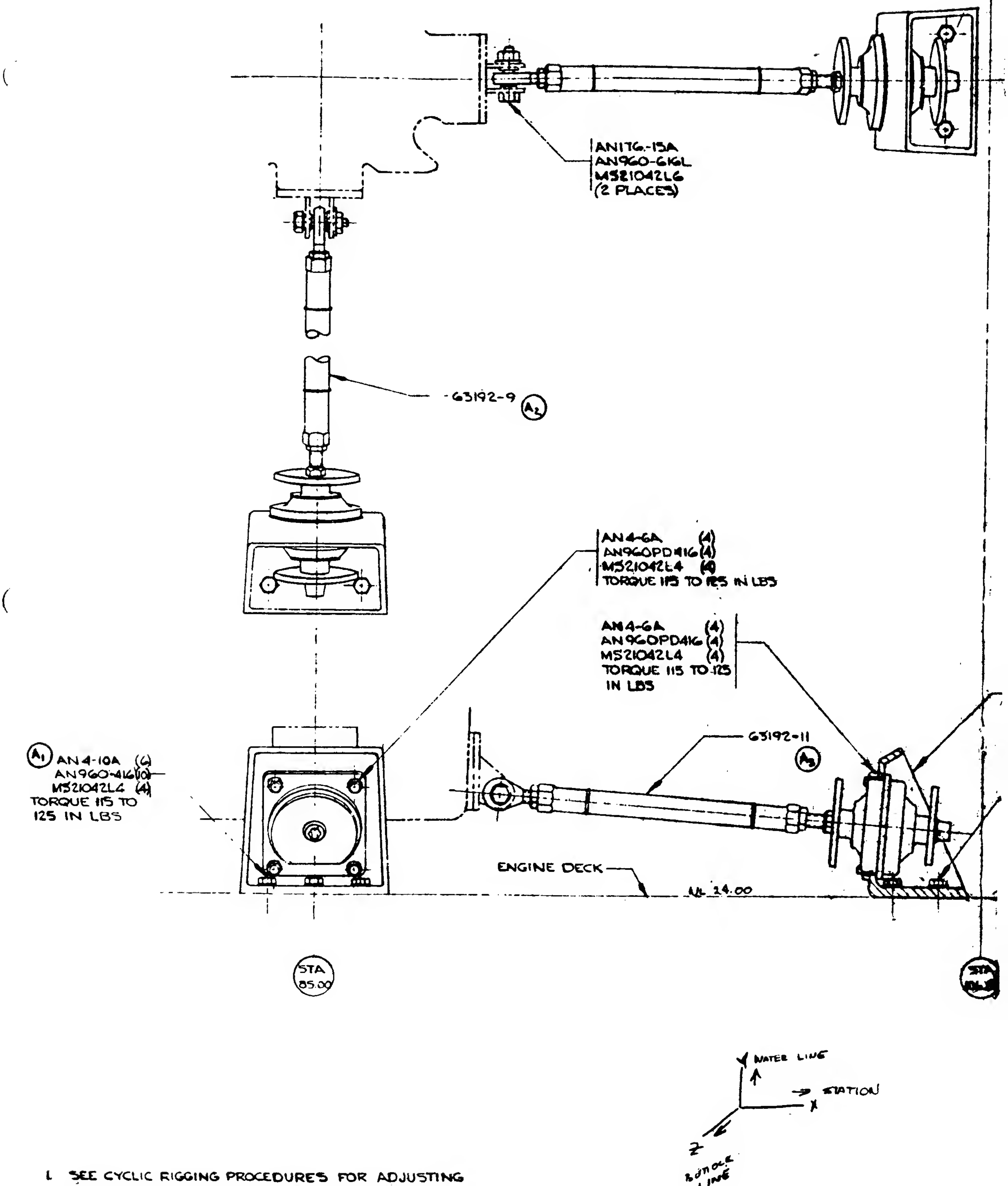


Exhibit B-4: Cushion Mounts for Bottom of Engine.



1. SEE CYCLIC RIGGING PROCEDURES FOR ADJUSTING SNUBBER TUBES TO APPROPRIATE LENGTHS.

NOTES:

Hiller Aircraft Company II (C)

Structural Bracket Design[1]

The engine supporting structure used on the Hiller helicopter models 12-E and 12-L consists of triangular struts formed from steel tubing ranging from 7/8" to 1 1/8" diameter. The triangular struts are formed of steel tubing joined with steel brackets. Several types of brackets are used in the mounting structure. Some attach to cushioned engine mounts; some merely join two struts; some attach the entire engine assembly to the airframe of the helicopter. An example of the latter type can be seen in Exhibit C - 1a.

Engine Mounting Structure

The complete engine mounting structure is shown in Exhibits C -1b through C - 1d. The structure is symmetrical about a vertical plane running fore and aft through the gimbal point, with the exception of several brackets on the left hand side which are bolted, instead of welded, to the steel tubing. The original intention of the bolted construction on one side was to allow easier removal of the engine for servicing. Due to the wieght of the engine (517 lbs.) and the irregularity of its shape, however, removal from the mounting structure proved impractical.

The bolted brackets on the left side are helpful, however, when major repairs are being made to the engine while it remains in the helicopter. Reasons for this can be seen in Exhibit 5 of the case "Hiller Aircraft Company, II (A)." From this exhibit, the relative locations of the right and left hand cylinders can be seen. Because the right hand cylinders are mounted low in the engine, the removal of the vertical side strut is not necessary during an engine overhaul. On the left hand side, however, where the cylinders are mounted higher, the vertical side strut limits accessibility to the upper cylinder. Hence, it is helpful to remove this strut while working on the left hand cylinders.

The steel tubes from which the struts are made are not produced by Hiller. They are made to Hiller specifications by a company in Los Angeles which specializes in this type of structural element. Hiller purchases the tubes with completely closed ends and machines all slots into which mounting brackets are welded.

---

1. This case is based upon a helicopter redesign problem described in "Hiller Aircraft Company, II-A, Design of a Supercharger Inlet Duct".

Prepared in the Design Division, Department of Mechanical Engineering, Stanford University by Eugene J. Echterling under the direction of Professor Henry O. Fuchs as a basis for student exercises. The assistance of Alfred Bolton and William Lancaster, Jr. of Hiller Aircraft Company is gratefully acknowledged.

The process of rounding tube ends is called "bull-nosing" and is quite commonly done on structural tubing used in the aircraft industry. Bill Lancaster explained how this operation is performed, "It is quite similar to forging, but is a somewhat more delicate operation. The material is usually brought to a high temperature, then formed in dies which close the ends. The process results in a build-up of material at the tube ends, permitting better load distribution when the tube is welded into a structural assembly."

Bill explained another reason for the use of closed ends on structural tubing, "In addition to offering a structural advantage, closed tubing ends protect the structure from corrosion on the inside. All exposed tubes must have closed ends for this reason. If such things as moisture, salt water spray, and corrosive insecticides are allowed to enter sections of confined tubing, they are difficult to remove and can cause the tubing to corrode from the inside. This can result in an undetectable weakening of the structure."

There are small vent holes in the tubing to vent gases built up during the welding of the brackets and tubing. After cooling of the welded assembly, pins are driven into these holes to seal the tubes.

The two rear lower brackets are the same, with the exception that the left hand bracket has one bolted joint and one welded joint instead of two welded joints (the welded bracket is shown in Exhibit C-2). The same is true for the two front lower brackets.

The brackets for the lower rear are machined from the extrusion shown in Exhibit C-3. The bracket is asymmetrical because of the difference in loads exerted on the adjacent joining tubes. Bill Lancaster explained that, for the same reason, some members of the mounting structure have different diameters.

The extrusions are purchased by Hiller and are cut to length and machined in Hiller machine shops. To provide proper loading conditions on the bracket, the intersection of adjacent tube center lines should be at the hole center for the bolt which attaches the bracket to the engine deck. The machining drawing for the finished bracket is to assure that the final configuration results in proper loading conditions on the bracket.

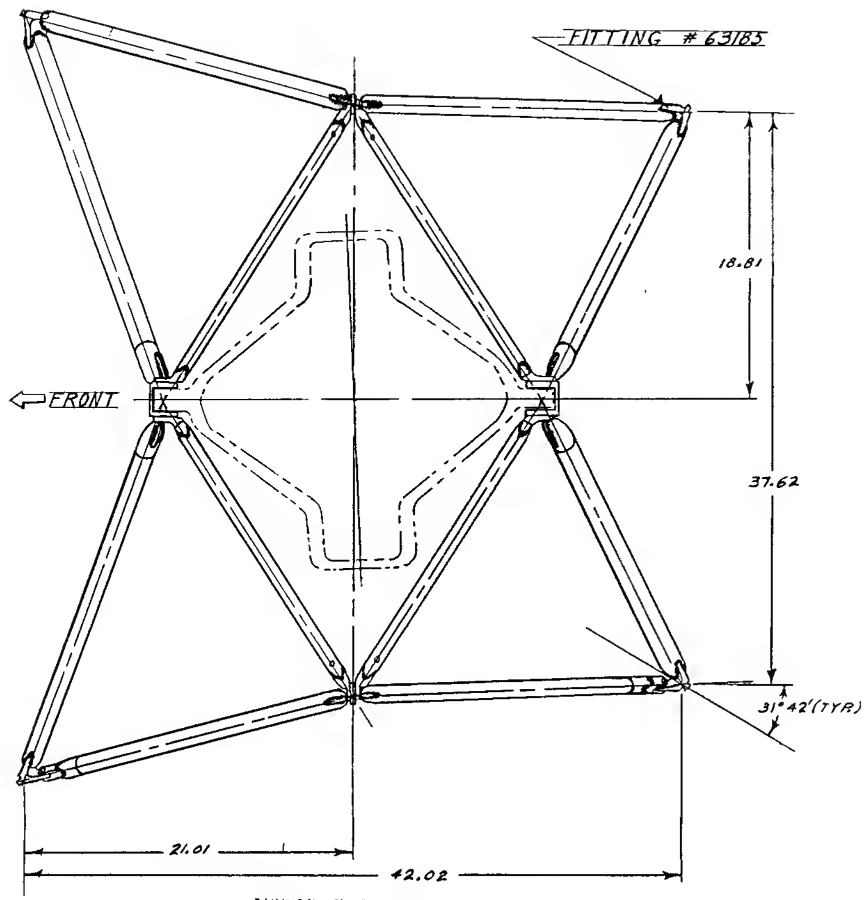


Exhibit C-1b: Plan View of Engine Mounting Structure.

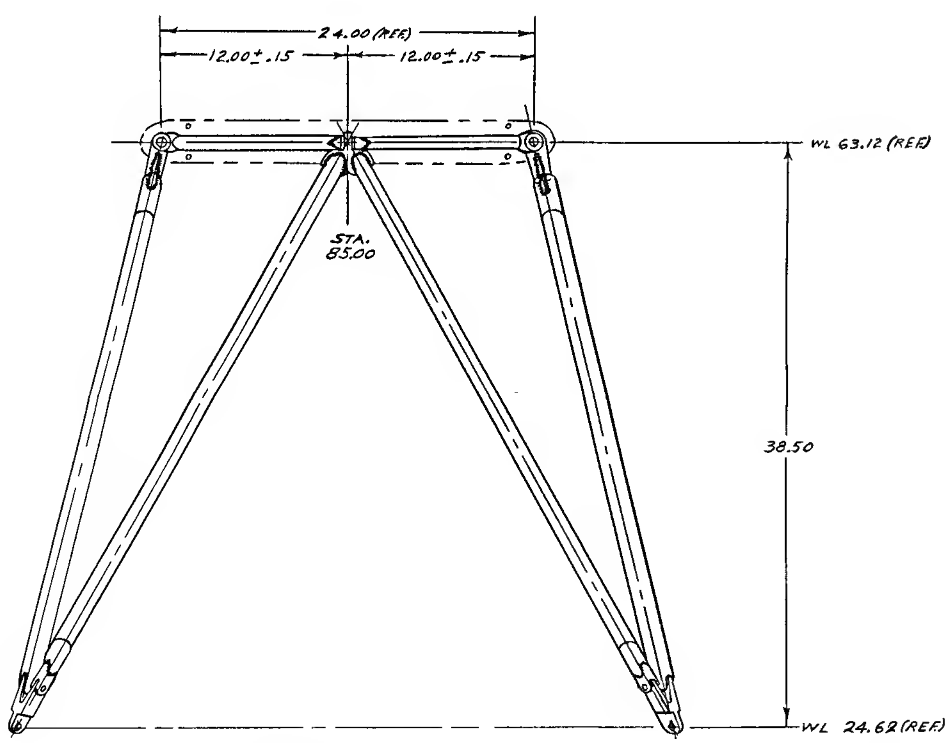


Exhibit C-1c: Left Side View of Engine Mounting Structure.

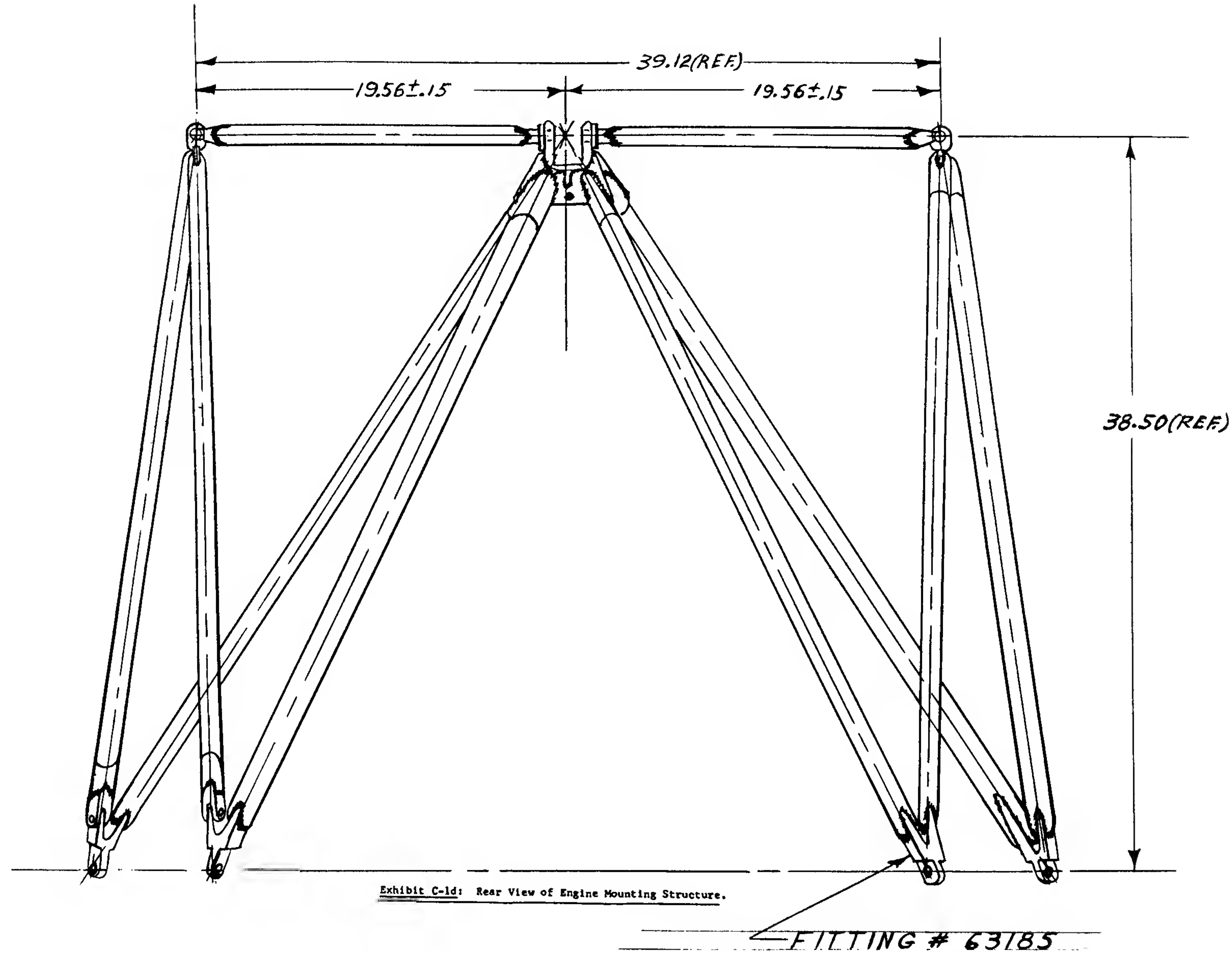


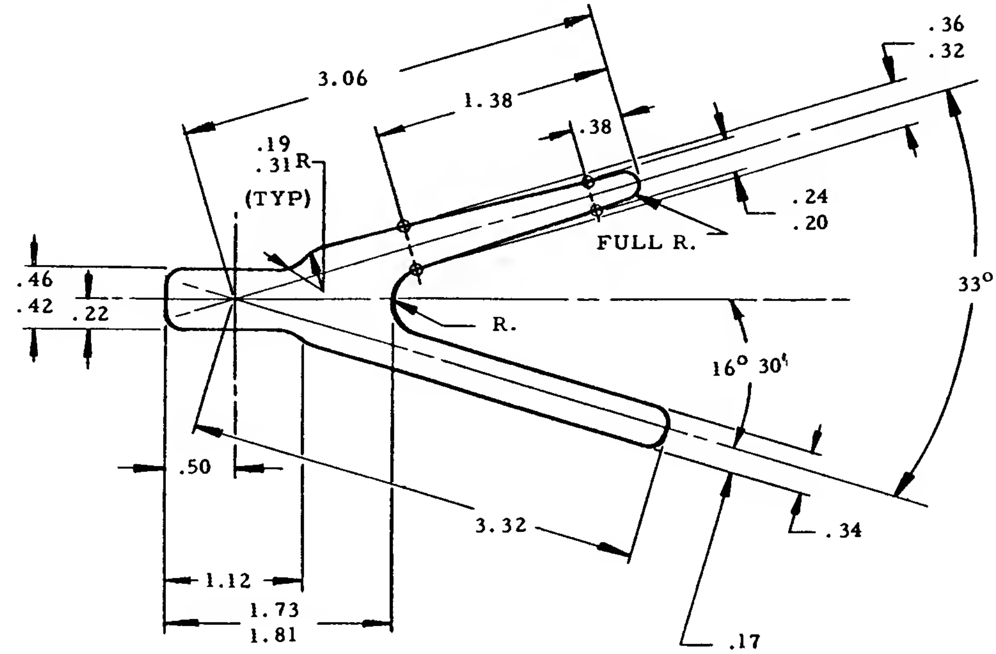
Exhibit C-1d: Rear View of Engine Mounting Structure.

Exhibit C-3: Extrusion Specifications for Bracket #63185.

ENGINEERING STANDARD

SECT 26

CODE IDENT.
89446



SCALE: NONE

NOTES:

MATERIAL: 4130 STEEL, SPEC. MIL-S-6758, COND. D-2

TOLERANCE: TWO PLACE DIMENSIONS ± .03, ANGULAR ± 1°, UNLESS OTHERWISE SPECIFIED.
TWIST = 1° PER FOOT, NOT TO EXCEED 5° FOR ANY TOTAL LENGTH.
STRAIGHTNESS = .025 MAX. PER FOOT DEVIATION.

FINISH: SURFACE ROUGHNESS HEIGHT RATING 250 PER MIL-STD-10. ALL EDGE RADII .12 UNLESS OTHERWISE SPECIFIED.

IDENTIFICATION: PER H. P. S. 1.21

INSPECTION: HOLD TO HS1007

ENGINEERING INFORMATION:

SAMPLE DRAWING L/M CALLOUT

	X		-X	FITTING, ENG. MOUNT	HS1007	
REQ ASSY		CODE IDENT.	PART NUMBER OR IDENTIFYING NO.	NOMENCLATURE OR DESCRIPTION	SIZE/DESCRIPTION	SPECIFICATION
					MATERIAL	

LIST OF MATERIAL

USE ONLY THOSE DASH NUMBERS AND MATERIAL CODES LISTED. ASSIGNMENT OF ADDITIONAL DASH NUMBERS AND MATERIAL CODES SHALL BE BY ENGINEERING STANDARDS GROUP.

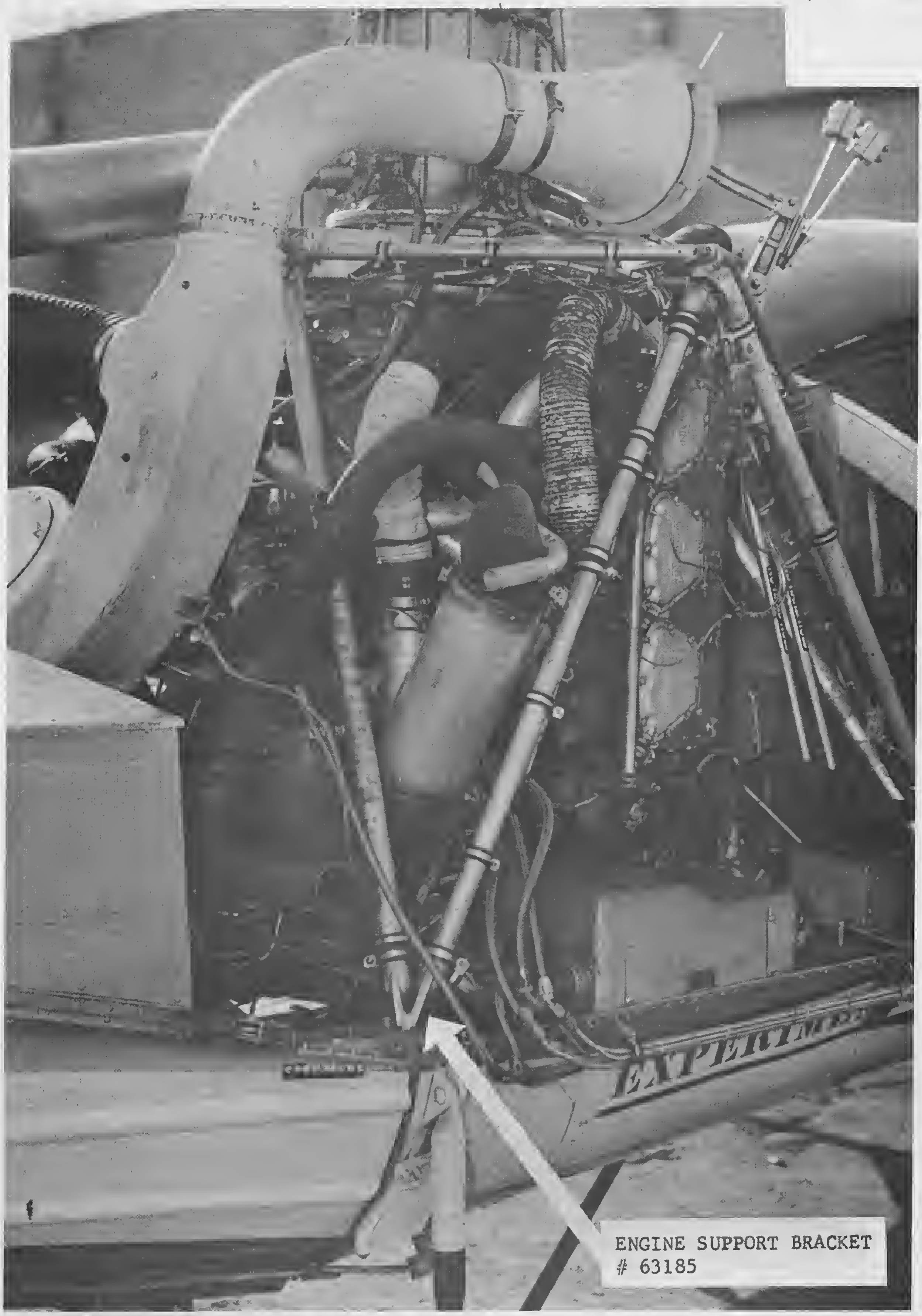
② ADDED TWIST & STRAIGHTNESS TOLERANCES. 1.73 - 1.81 DIM., WAS 1.76

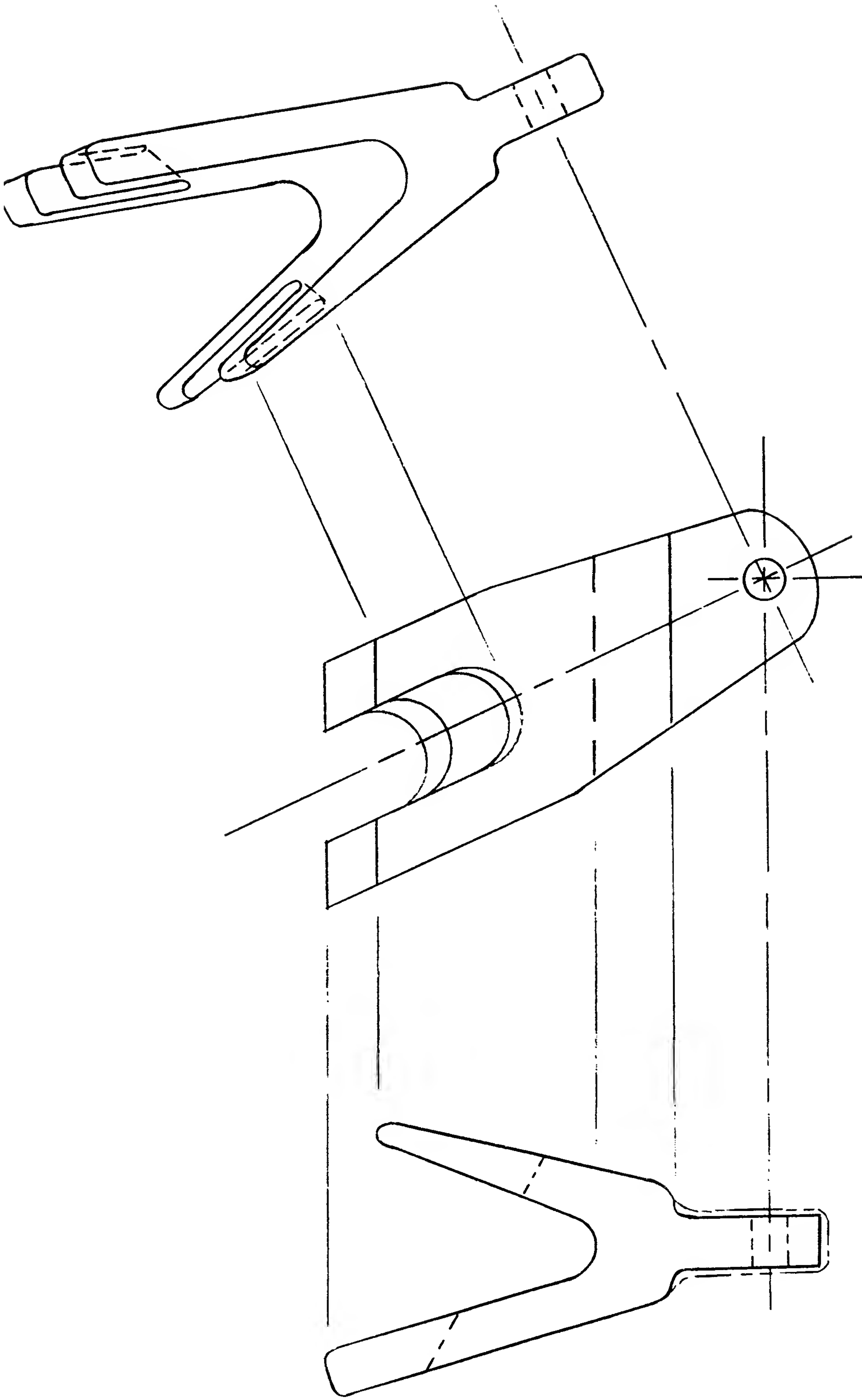
EXTRUSION, 33° "Y"

HS 1007

SHEET 1 OF 1

Exhibit C-2: View from Right Side Showing Engine Mounting Structure.





C-4:
Bracket # 63185
Machining Drawing

HILLER AIRCRAFT COMPANY II-D

Engine Shroud Design[1]

In 1949, when the first model UH-12 helicopter was designed, consideration was given to the design of an engine shroud. This was done in the later stages of the overall design, after the engine, mounting structure, and airframe had been designed. Because of cooling problems arising from the addition of a shroud, however, the engine was left uncovered.

Bill Lancaster, power plant engineer on the present model UH-12E, commented, "Any new ship designed today would be completely enshrouded, with much more attention given to shroud design than was given to the shroud on our 1949 model."

Bill said appearance is one important reason for an engine shroud. The sales appeal gained by addition of a shroud is more important for commercial rather than military users, however. The military attaches a great deal of significance to accessibility for servicing the aircraft. For military users, who must often service their aircraft under front-line combat conditions, accessibility cannot be sacrificed for a consideration based only on appearance.

Visibility is another consideration related to design of an engine shroud, since a helicopter is quite often used as an observation vehicle. The addition of an engine shroud can affect rearward visibility if the shroud is much larger than the engine.

He explained that aerodynamic drag is another consideration related to shroud size. Although some reduction of aerodynamic drag would result from the addition of an engine shroud to the present UH-12L, Bill believed that this would be of borderline significance since the most important drag consideration is the front profile of the ship. Any shroud to be added must stay within the limits of this present front profile, which is the result of wind tunnel tests and is a very basic element of helicopter design. An extensive change in front profile could require other design changes, such as rotor system or power plant.

Cooling problems arising from addition of the shroud designed in 1949 led Hiller engineers to decide against the use of a shroud on successive models (A through E) of the UH-12. The engine has forced air

1. This case is based on a helicopter redesign problem described in "HILLER AIRCRAFT COMPANY, II-A; Design of a Supercharger Inlet Duct".

Prepared in the Design Division, Department of Mechanical Engineering, Stanford University, by Eugene J. Echterling under the direction of Professor Henry O. Fuchs as a basis for student exercises. The assistance of Alfred Bolton and William Lancaster, Jr. of Hiller Aircraft Company is gratefully acknowledged.

cooling supplied by a fan mounted on the front side of the engine. The cooling air is drawn from the air flow over and around the passenger compartment. The air is forced past cooling fins on the engine cylinders and out the back side of the engine. A cowl, mounted on the front of the engine, directs the air through the engine structure and through an oil cooling radiator mounted on the left side of the engine deck (Exhibit 5 of part A).

Bill Lancaster explained that if an engine shroud was to be added to the present model 12-L, points of attachment might be the engine deck, engine mounting structure, or the back of the passenger compartment (Exhibits 1-D). He felt that engine motion during operation would make attachment to the engine impractical.

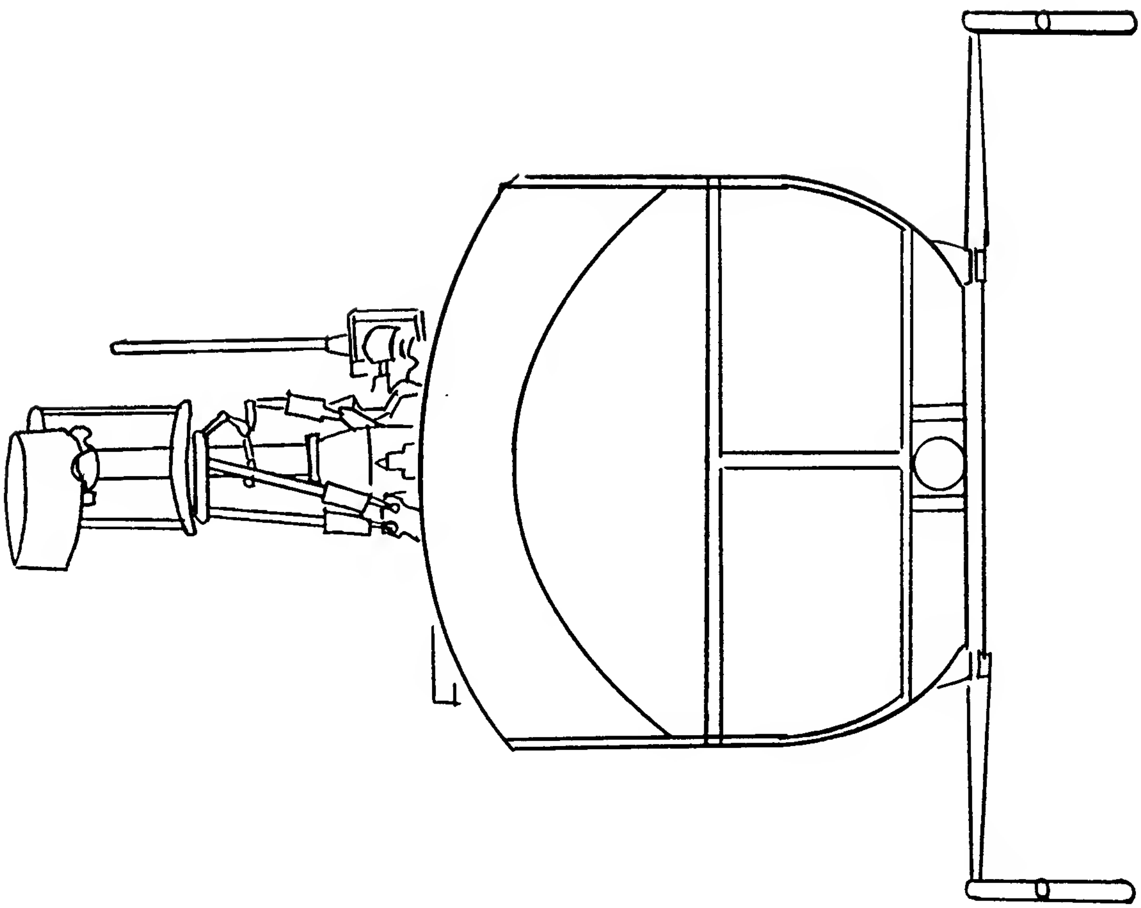


Exhibit 1-D: Hiller Model UH-12

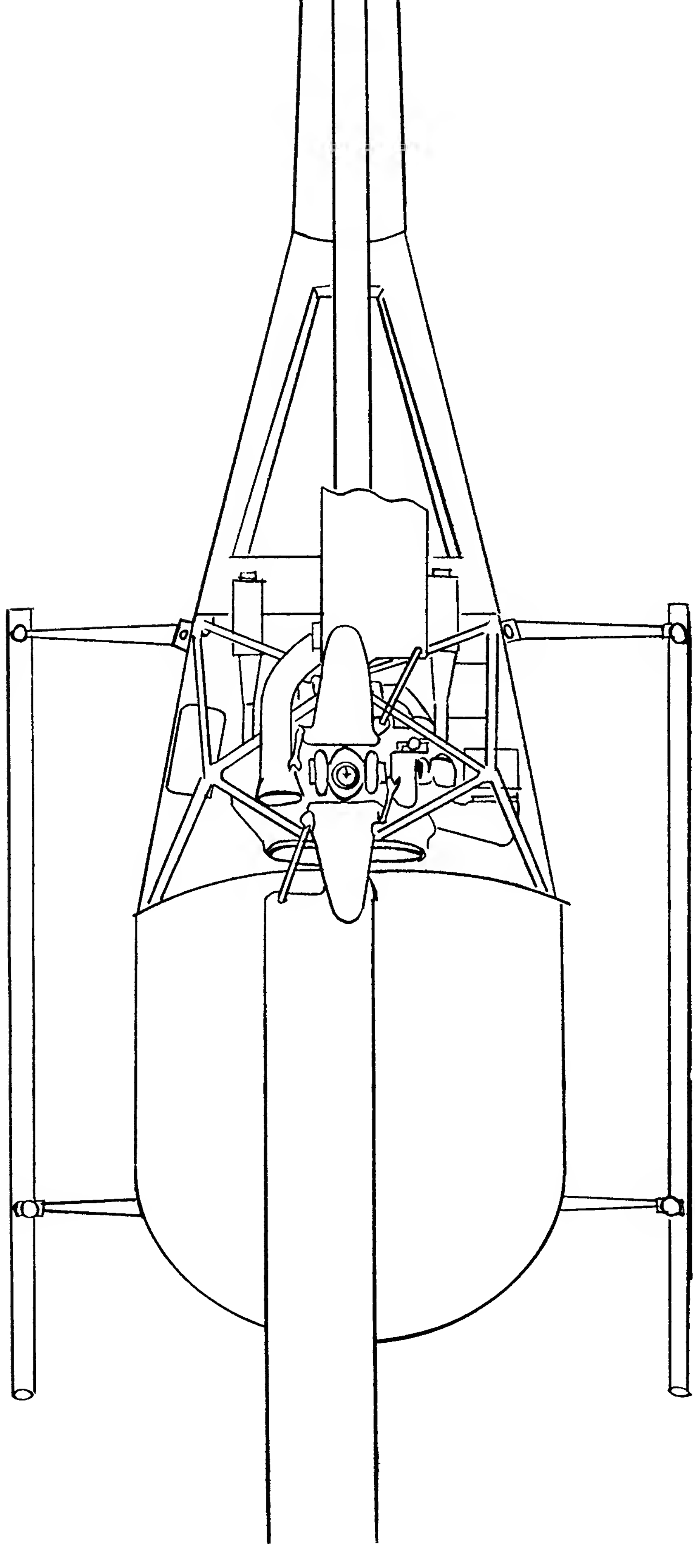


Exhibit 1-D:
(cont.)

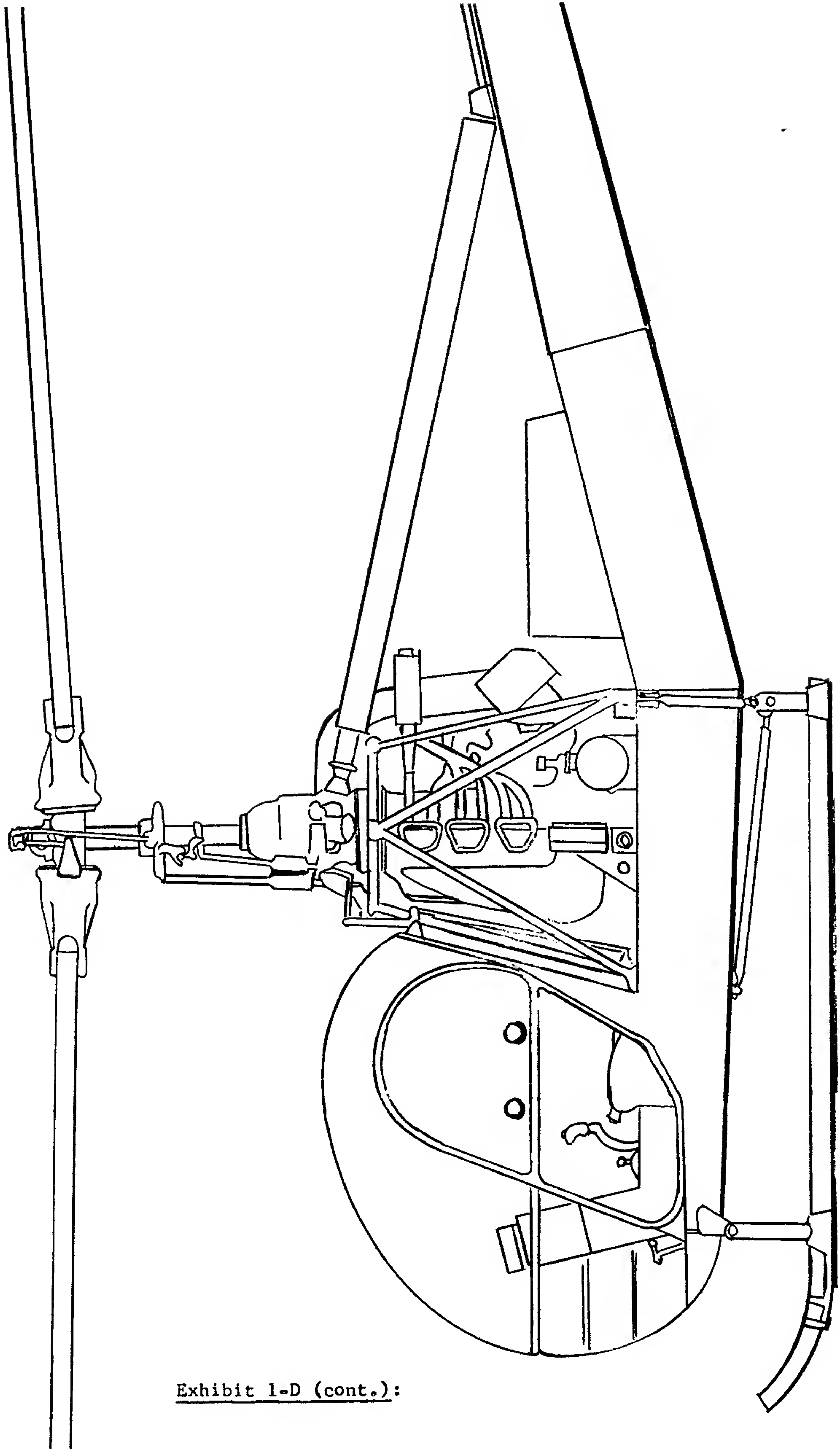


Exhibit 1-D (cont.):